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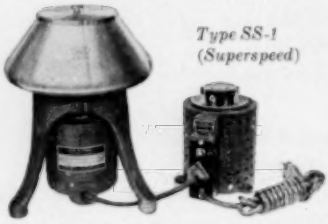

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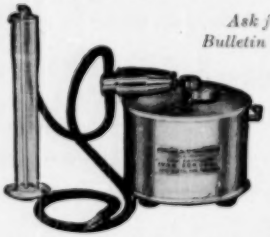

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THE QUARTERLY REVIEW *of* BIOLOGY

THE THYROID GLAND AND ITS FUNCTIONS IN COLD-BLOODED VERTEBRATES

BY W. GARDNER LYNN AND HENRY E. WACHOWSKI

The Catholic University of America

I. INTRODUCTION

THE thyroid gland was known to a number of early Greek and Roman writers who also recognized goiter as a pathological enlargement of the organ. The name "glandula thyreoidea" was first used by Thomas Wharton, in 1656, in the first thorough account of its anatomy. It was not until the latter half of the nineteenth century, however, that the significance of the thyroid as an endocrine organ regulating metabolic activity was recognized. Following this discovery much interest was aroused in studies of thyroid morphology and physiology in the human being, and in mammals in general, and these studies rapidly yielded results which proved of great therapeutic importance. Investigations dealing with the embryology and morphology of the thyroid in lower vertebrates were less numerous, but the existence of the gland in all vertebrate groups and possibly even in some protochordates was soon demonstrated. Early attempts to elucidate the function of the thyroid by means of thyroidectomy in lower vertebrates, such as salamanders and reptiles, only resulted in the death of the operated animals, however, and led to the erroneous conclusion that the presence of a functional thyroid is necessary for life. It was not until Gudernatsch's (1912) discovery of the role of the thyroid in control of amphibian metamorphosis that extensive experimental study of thyroid function in cold-blooded vertebrates was undertaken. This study has become increasingly active through the years, and although the phenomena of amphibian metamorphosis still occupy the center of interest, we now have available a considerable body of information on the thyroid gland and its functions in developmental stages and in the adult in fishes, amphibians, and reptiles.

II. GENERAL MORPHOLOGY

The thyroid in cold-blooded vertebrates, as in higher forms, is a follicular, highly vascular organ located in the cervical region. It is unpaired in cyclostomes, fishes, and reptiles, but is usually represented by at least two discrete bodies in amphibians. Goldsmith (1949) has given an excellent review of the phylogeny of the thyroid, and one considerably more extensive than the present account can be. That the gland may be represented in protochordates was first suggested by Müller (1871), who regarded the endostyle of *Amphioxus* and the tunicates as a possible thyroid homologue. This hypothesis has been much discussed but remains controversial. A recent student of the subject (Leach, 1939) has stated that the evidence for homology of the thyroid with the protochordate endostyle is still inadequate. On the other hand, he has supported the earlier findings of Marine (1913) that the thyroid of the adult lamprey is formed by differentiation of certain cells derived from the endostyle of the ammocoetes larva. In all adult cyclostomes the thyroid consists of a number

of diffusely scattered follicles lying in the gill region below the pharynx (Leach, 1939).

The thyroid of an elasmobranch, *Squalus*, was first described by Müller (1871), who reported that this fish possesses a persistent thyroglossal duct. Goodey (1910) found a similar condition in *Chlamydoselachus*, but Norris (1918) failed to confirm that a thyroglossal duct is present in *Squalus*. Hill (1935) has described the thyroid of the holostean, *Amia*, which consists of groups of follicles scattered about the ventral aorta.

The first account of the teleost thyroid was given by Simon (1844), who, however, reported that the gland is absent in salmonoid fish. Other important early contributions to knowledge of thyroid morphology in bony fishes were made by Maurer (1886), and Gudernatsch (1911). The latter, in a comparative study of thyroid tissue in 29 species of teleosts representing 20 different families, reported extremes of arrangement of the tissue from compactly united to diffusely scattered follicles, with a predominant tendency toward the diffuse, scattered condition. This is supported by the later work of Burne (1926) on the angler fish, *Lophius*, and of Hoar (1939) on the Atlantic salmon. Several notable exceptions to this prevailing pattern of dispersion of thyroid follicles in the teleosts have been reported, however. The swordfish, *Xiphias gladius* L., has a thyroid that forms a large, well-circumscribed mass situated at the cephalic end of the ventral aorta and composed of four well-defined portions (Addison and Richter, 1932). Matthews (1948), upon examining three genera of parrot fish (*Pseudoscarus*, *Sparisoma*, and *Scarus*), found that in each case the thyroid was a broad, elongate, compact mass separated into anterior and posterior portions by the first afferent branchial artery.

Among early accounts of the thyroid gland in amphibians are those of Leydig (1853) on *Triton*, Müller (1871) on *Rana*, Wiedersheim (1884) on a number of anurans and urodeles, and Maurer (1888) on urodeles. In these forms the gland typically consists of two lobes, each enveloped in a membrana propria. The latter surrounds not only the follicles and the intervening lymph spaces, but also the inferior jugular vein in the region of the gland. The lobes are covered medially by the geniohyoid muscle, laterally by the internal hyoid of the first branchial arch, and dorsally by the sternohyoid muscles. In addition to the main portions of the gland, accessory thyroids occur with considerable frequency. The thyroid gland of *Necturus* (Charipper, 1929; Webster, 1934) is composed of three distinct masses, a median anterior, a right lateral, and a left lateral lobe. The median mass frequently shows linkage to the lateral masses by chains of follicles.

The major point of difference in the gross morphology of the thyroid in amphibians seems to be in its blood supply. Maurer (1888) described for *Triton* a "rete mirabile" arising from a branching of the large jugular trunk. Baldwin (1918) found that in *Ambystoma punctatum*, although the blood supply is variable, there is no evidence for the origin of the "rete" from the jugular. He maintained that the interfollicular network is formed from small venous twigs coming from vessels in the sternohyoid or geniohyoid muscles, and never from the main jugular trunk. A connection with the external carotid artery was shown in a single case among his specimens. Charipper (1929) however, demonstrated for *Necturus* a blood supply that is primarily arterial. He found the capillary network of the thyroid to be in communication with the jugular sinus, but he could discover no large vein directly connected with the gland.

The gross morphology of the thyroid gland in reptiles closely approaches that found in higher vertebrates. Baldwin (1918), in his review of the thyroid, has referred to the reptilian organ simply as a single, lobulate, follicular structure, which contains colloid, and lies close to the trachea. In the turtle, *Chrysemys*, the thyroid has been described (Shaner, 1921) as a flattened mass ventral to the truncus arteriosus at the origin of the great vessels leaving the heart. It exhibits a cord-like arrangement, with large lumina filled with a reddish secretion. Adams (1939) found that the thyroid of *Lacerta* derives its blood supply from both the systemic and pulmonary circulations.

III. EMBRYONIC ORIGIN

Descriptions of the origin of the thyroid gland in cyclostomes and fishes present, with one notable exception, a fairly consistent picture. The chief differences found in different species are in the nature of the thyroid anlage, which may be either hollow or solid, and in its mode of origin from the pharynx, a mode which varies from the formation of a long trough-like diverticulum to a localized outpushing of a spherical mass of cells. Stockard (1906) found that the thyroid of the lamprey, *Bdellostoma*, originates as a groove in the pharyn-

geal floor and extends through the length of the whole gill area. He pointed out that no other vertebrate is known to have a thyroid anlage of such length, but he attributed the condition to the extensive gill area of *Bdellostoma* and did not consider it evidence of any close phyletic relation to the endostyle of *Amphioxus* and the ascidians. As has been noted, however, later studies of the origin of the cyclostome thyroid have shown quite clearly that its cells are derived from certain elements of the endostylar region of the ammocoetes larva (Leach, 1939).

Norris (1918) described the thyroid of *Squalus* as arising in the form of a solid epithelial bud ventral and posterior to the first two gill pouches. Maurer (1886) found the anlage to be a hollow evagination of the pharyngeal floor in the trout, and Gudernatsch (1911) regarded this as applicable to teleosts generally. Hoar's (1939) study of the salmon indicates, however, that in this form the gland arises from a solid knob of cells at the level of the hyomandibular pouch.

Recently, Thomopoulos (1948) in a preliminary paper has reported for the salmon findings which are quite at variance with all preceding descriptions of the origin of the gland. He maintains that the salmon thyroid is mesodermal in origin, arises as an unpaired thickening in the pericardial wall, and has no relation to the pharynx. Acceptance of this view must wait upon presentation of more complete evidence.

Surprisingly, the literature on the origin of the thyroid gland in amphibians is none too extensive. Most work has concerned the later growth and differentiation of the gland in relation to metamorphosis. Webster (1934) has attributed the first account of the development of the gland in *Rana* to Müller (1871). The general pattern of development of the thyroid in amphibians was most comprehensively worked out by Maurer (1888), who studied the origin of the thyroid in a number of anurans and urodeles, including the axolotl. According to his findings, the primordium of the gland is an outpocketing that extends from the floor of the pharynx between the second pharyngeal pouch and the pericardial chamber. It now appears that Maurer was in error concerning the position occupied by the primordium, for more recent workers agree that it arises from the pharyngeal floor between the paired second visceral arches, or, in some forms, from the floor of the hyomandibular pouch. Maurer found that, chronologically, this primordium appears before the union of the gill pouches with the ectoderm. Shortly after hatching, the anlage separates from the pharyngeal floor and becomes an ovoid mass of cells. This body of cells then splits lengthwise into two parts, with an isthmus uniting the two. Some days later the two lobes become separated by the sternohyoid muscles, although a few elements of the forming gland may remain in the median line anterior to the two halves. According to Maurer, this represents the original isthmus. The two lobes now arrange themselves into solid cords and these differentiate into follicles holding the characteristic colloid. The principal point of disagreement in early accounts of development of the gland concerns the nature of the thyroid primordium itself. Maurer (1888) and Baldwin (1918) maintain that in urodeles the primordium is a solid mass of cells; and much more recently Dent (1942) has described a solid primordium for the thyroid of the urodele *Plethodon*. Platt (1896), however, found that in *Necturus* the thyroid primordium is vesicular. This view was supported by Webster (1934), but has been controverted by Sanders (1935). Maurer (1888) stated that in anurans the primordium begins as a vesicular structure which later becomes solid, but Müller (1871) found that the thyroid rudiment is solid from the beginning in *Rana temporaria* and *R. platyrrhinus*. It is interesting that similar disagreements have already been noted concerning the thyroid primordium in fish. The point may possibly have bearing on phyletic considerations involving the two groups.

Heidenhain (1921) described for mammals two types of follicular structure; an association type, in which follicles developing from primary cell columns remain in epithelial continuity, and a dissociation type in which the follicles become separated. Uhlenhuth and Karns (1928) found that follicular formation in *Ambystoma opacum* is of the association type, and results in a thyroid composed of a coiled tube which appears sac-like at intervals, whereas in *A. maculatum* the gland consists of complex discrete follicles.

It has been previously pointed out that a splitting of the anlage of the gland results in its eventual paired condition in amphibians. James (1946) has demonstrated that the thyroid anlage will divide into two only when it can come in contact with a cartilaginous hyoid keel. If the adjacent cartilage mass is rod-like, the gland does not divide but encircles the cartilage.

In early studies of the origin of pharyngeal derivatives in reptiles specific consideration of the thyroid was not extensive. More complete accounts were given by Maurer (1899) and more recently by Shaner (1921), who studied the pharyngeal derivatives of the turtle *Chrysemys* by wax-plate reconstruction methods. He has described the thyroid rudiment as a mid-ventral outgrowth of the pharynx, between the first and second gill pouches. It remains attached to the pharynx for a time by a slender cord but eventually breaks free and becomes the single unpaired body characteristic of the group. Shaner's findings for *Chrysemys* are confirmed by Naccarati's (1922) study of a related genus, *Emys*, and Hammar (1937) reported essentially similar observations for the origin of the thyroid in the Crocodilia.

IV. HISTOLOGY AND CYTOLOGY

Investigations of the finer structure of the thyroid are so much more extensive for the amphibians than for other cold-blooded forms that it seems advisable to consider this group first. It must be noted at the outset that one of the outstanding features of the histology of the thyroid in amphibians is its great variability in different individuals, even under seemingly identical conditions. This variability far exceeds that found in warm-blooded vertebrates and must constantly be borne in mind when changes in histological appearance are utilized as criteria of the effectiveness of experimental treatments. Uhlenhuth, Schenthal, Thompson, Mech, and Algire (1945) as a result of a critical statistical study found, for example, a variability of 21.0 per cent in colloid level in the normal thyroid of *Triturus*, compared with a variability of 5.1 per cent for the guinea pig, and a variability of 18.0 per cent in cell height in the salamander compared with 1.8 per cent for the guinea pig. They pointed out that such differences do not seem explicable on the basis of the known physiological roles of the salamander thyroid and must be attributed to what might be called a general instability of amphibian endocrines. Despite this variability it is, of course, possible to present a generalized picture of thyroid histology for a given species, and this has been done in a number of outstanding contributions which have been fully reviewed by Eggert (1938).

As in vertebrates generally, the amphibian thyroid consists of follicles each made up of a single layer of epithelial cells and containing a greater or less amount of colloid in its lumen. The follicles are surrounded by a connective tissue framework which is highly vascular. Detailed descriptions of the histology of the gland in amphibians center about five of its features: a) the epithelial cells forming the walls of the follicles, b) the stainable colloid within the follicles, c) non-stainable intrafollicular "vacuoles," d) intracellular structures associated with secretory activity, and e) possible structures associated with release of the thyroid secretion.

Charipper (1929) described two principal kinds of cells in the thyroid of *Necturus*. One type corresponds to the so-called chief cell and varies in size and shape from low cuboidal to high columnar, with a nucleus that is rounded. The cytoplasm is clear, light-staining with eosin, and contains numerous granules and vacuoles. A second cell type, the colloid cell, first described by Langendorff in 1889, characteristically contains one or more large colloid droplets in the cytoplasm, and has a nucleus that is basal in position, spherical, and granular. Both these cell types contain mitochondria, granular or filamentous, distributed throughout the cytoplasm. Filamentous and granular mitochondria have also been reported for *R. esculenta* by Hirschlerowa (1928) and for *Amblystoma* by Uhlenhuth (1928). The former author also pointed out that an increase in mitochondrial size occurs at metamorphosis. Charipper described the Golgi apparatus as a network situated on the follicular side of the nucleus, although the amount, extent, and position of the network is apparently extremely variable. Typically it extends to the follicular margin of the cell, where it ends in a condensation of fine granules. The Golgi apparatus is not as extensive in the colloid cells as it is in the chief cells. D'Angelo and Charipper (1939) found that in the early stages of development in *R. pipiens* the apparatus has a small, compact configuration, changing later to a highly elaborate network that may be either filamentous or ring-like.

Features characteristically present in the thyroid gland are vacuoles, which may appear in the periphery of the follicular colloid as well as in the follicular cells themselves in material prepared with the usual fixatives and stains. These vacuoles were first described by Anderson (1894). He pointed out that the intracellular vacuoles under certain conditions seemed to communicate with vacuoles in the follicular colloid and he therefore considered

them as antecedents of the vacuoles in the colloid. Because they normally fail to stain, he called them a "chromophobe secretion." Since then many investigators have studied these vacuoles and have attempted to ascertain what role they may play in the activity of the thyroid (see Ponse's review, 1938). Bensley (1916) and Uhlenhuth (1925b, 1927, 1928) were able to stain the vacuoles and agreed in part with Anderson's observations. Aron (1930) and Severinghaus (1933) on the other hand considered them resorption phenomena, and postulated that their presence indicated a high rate of absorption of colloid from the follicle. Uhlenhuth (1925a) succeeded in observing these vacuoles in living thyroid tissue, and thus demonstrated that they were not fixation phenomena, as some authors had maintained, but were integral functional features of the gland. Williams (1937) observed vacuoles in living thyroid follicles in the rabbit, but stated that they are unlike the vacuoles normally seen in fixed and stained preparations. Grant (1930c, 1931a), in a study of the *Necturus* thyroid, presented a picture in substantial agreement with that proposed by Aron (1930). She found that in thyroids stimulated to secretion there is a liquefaction of the stored colloid, with a change in its staining properties, as a response possibly to a digestive activity of the epithelial cells, and further an absorption of this material in the form of droplets or vacuoles in the cells. Uhlenhuth (1937) came to essentially the same conclusions and also postulated the presence of a proteolytic enzyme, thyreodase, excreted into the lumen of the follicles for transformation of the colloid into a substance capable of passage through the apical membranes of the cells (Uhlenhuth, 1939). De Robertis (1949) has shown that when the freezing-drying technique is used, no vacuoles whatsoever appear in the colloid within the follicles, although colloidal vacuoles and droplets are present within the cells themselves. He therefore considered these marginal vacuoles as artifacts, although agreeing in substance with the resorptive concept in so far as the droplets in the cells are concerned.

The staining reaction exhibited by the colloid stored in the lumina of the thyroid follicles varies from acidophilic to basophilic. Hewer (1927) has stated that the colloid of inactive follicles is acidophilic, while that of active follicles is basophilic. Uhlenhuth (1939) found that, while the follicular colloid of the actively secreting gland stains basophilically, the intracellular colloid droplets take an acid stain. Basophilic intracellular vacuoles have been reported, however, by Grant (1930c) and Uhlenhuth (1927, 1937) as occurring regularly in both active and inactive glands of the Amphibia. D'Angelo (1941) found in the thyroid of *Rana* at metamorphic climax intracellular droplets of both acidophilic and basophilic types, while in early glands only acidophilic droplets were detected with any frequency. He suggested that the differential staining of these droplets may be a means of distinguishing "storing" colloid (acidophilic) from "releasing" colloid (basophilic). It must be mentioned that with the freezing-drying technique, as applied to the gland by De Robertis (1949), all follicular colloid stains blue, with no evidence of red or orange staining such as is obtained with the usual fixation and Mallory-Azan stain. This seems to indicate that an artifact is responsible for the color differences so far reported. It should be pointed out, however, that the diagnostic value of the color differences, even if they are artifacts, does not seem to be overthrown.

The problem of colloid release is an especially difficult one to resolve on the basis of the available evidence. Uhlenhuth (1927) postulated the release of colloid from the follicle by an intercellular route, and described the presence of colloid droplets between cells. This view was supported by Hirschlerowa's (1928) report of the existence of intercellular canals between the follicular lumen and the peripheral blood supply. Brink (1939) also claimed to have found intercellular canals in the thyroid of the anuran *Arthroleptella*. Williamson (1923) described micro-capillaries in the secreting epithelium of the gland, but this report has been seriously questioned by Wilson (1929), who seems to have established quite conclusively that the so-called capillaries are in reality terminal bars.

A very different concept of the mode of colloid release was presented by Grant (1930c), whose work on the activated thyroid of *Necturus* led to the conclusion that the colloid leaves the follicular lumen by passing through the cells themselves. Later studies of a similar nature on *Amblystoma* (Grant 1931a, b) gave further evidence for this hypothesis, for it was noted that there was a direct ratio between the amount of intracellular colloid and the extent of stored colloid release, as shown by the collapse of the follicles. This ratio seemed explainable only in terms of transcellular

transport. The same pattern of follicular collapse was reported for the toad by Magdalena (1932) but Uhlenhuth, Schenthal, Thompson, and Zwilling (1945) pointed out that this is by no means a universal phenomenon accompanying thyroid activity.

De Robertis (1949) stated that in the guinea pig and rat after treatment with thyroid stimulators there is an initial period of active secretion toward the lumen of the follicle and that this period is followed by secretion toward the base of the cell, with simultaneous reabsorption of the colloid stored in the lumen. De Robertis and Del Conte (1942), however, reported that the first phase was not observed in the amphibian thyroid. Uhlenhuth, Schenthal, Thompson, and Zwilling (1945), following exhaustive experiments on the thyroid of *Triturus torosus* stimulated with thyrotrophic hormone, presented what is possibly the most convincing picture of colloid storage and release as it occurs in amphibians. Their experiments show that thyroid activity following stimulation is divisible into two stages. There is a period of initial release, during which all stored colloid that can be released by the dose of activator administered and the individual specimen is released. This is then followed by a stage of maximal activation, during which newly elaborated colloid is discharged into the lumen of the follicle. This work also seems to show that the thyroid function is cyclic, so that emptying of the follicle is followed by secretion into the follicle, no matter how much the thyroid is stimulated. There is no evidence of secretion directly from the basal pole of the epithelial cell into the blood stream. Both secretion and absorption seem, therefore, to be functions of the apical pole of thyroid cells. The apparent necessity of repassage of the colloid from the lumen through the cells suggests that stored colloid is different from the colloid finally excreted; that some necessary final change occurs before it is delivered to the blood stream. The authors have also correlated the pattern of secretion and release with the cell height of the follicular epithelium, and have found that cell height increases during initial release, and remains high during maximal activation.

Much of the work on the histology of the amphibian thyroid has been done in connection with investigations of the relation between thyroid activity and metamorphosis and studies of seasonal variations in metabolic activity. These subjects will be considered in later sections of this paper.

The histology of the cyclostome thyroid has been most fully described by Leach (1939), who found that after definite follicles have been formed from certain cells of the larval endostyle, they remain in an inactive condition for some time and show no stainable colloid until approximately four months after the onset of metamorphosis. In the adult lamprey, however, the structure of the follicle is quite similar to that described for amphibians. Study of the histology of the fish thyroid reveals that here too, despite the usually diffuse nature of the gland, the fundamental units resemble those of higher vertebrates, and changes in epithelial height and staining reaction of the follicular colloid accompany alterations in the rate of secretory activity (Murr and Sklower, 1928; Lieber, 1936; von Hagen, 1936; Hoar, 1939; Buchmann, 1940; Collamand and Fontaine, 1942; Robertson, 1948, 1949). A most striking feature of the fish thyroid, and one which has not been reported for other cold-blooded forms, is the fact that it not uncommonly exhibits marked pathological enlargement, which has been variously described as a goiterous or tumerous condition. Histologically these vary from simple hyperplastic growths to nodules like those seen in thyroid adenoma in the human. However, in certain cases they present an appearance characteristic of malignancy and may extensively invade surrounding tissues. Certain salmonoid fish seem to be most susceptible to this condition, but it has also been reported in several other teleosts. (See the recent review by Lucké and Schlumberger, 1949.)

Histological studies of the reptilian thyroid incidental to various experimental studies reveal no unusual features (Eggert, 1933, 1936; Hellbaum, 1936; Ratzersdorfer, Gordon, and Charipper, 1949). However, it may be noted that Mason (1938) has described the snake thyroid as exhibiting a remarkably constant histological picture, showing even less variability than that of the guinea pig, and therefore suggests its use as a test object for the assay of thyrotrophic hormone.

V. THE ROLE OF THE THYROID IN AMPHIBIAN METAMORPHOSIS

The role of the thyroid gland in amphibian metamorphosis has been more extensively investigated than has any other aspect of thyroid function in cold-blooded vertebrates. This matter has also been the subject of several important reviews which have covered the literature up to about 1938 (Fulton, 1921; Rémy, 1923, 1924; Guder-

natsch, 1929; Allen, 1929, 1938; Bounhiol, 1942). The present account will therefore be largely restricted to studies which have been published since that time. In order properly to evaluate the significance of these studies, however, it will be necessary, in connection with several aspects of the subject, to give resumés of the main results of early investigations. The transformation of the aquatic tadpole into the terrestrial frog, a process that involves profound bodily changes, both morphological and physiological, has interested naturalists from very early times. By the end of the nineteenth century much information was available concerning the sequence in which the events of metamorphosis take place in different amphibians, the details of the changes occurring in the various organ systems, and the histological alterations exhibited by certain of the tissues. There was at that time, however, no clue as to the agency which calls forth these changes.

A. Induction of metamorphosis by treatment with thyroid substance, iodine, or iodine compounds

The discovery of the importance of the thyroid gland as a controlling factor in metamorphosis is to be credited to Gudernatsch (1912, 1914), who, in the course of experiments dealing with the effects of feeding certain specific mammalian organs to amphibian larvae, found that those animals which were fed horse thyroid gland, unlike those fed with any other tissue, showed a suppression of further growth and underwent an extremely precocious metamorphosis. This striking result of thyroid feeding was obtained both with anuran tadpoles (*Rana temporaria*, *R. esculenta*, *Bufo vulgaris*) and with urodele larvae (*Triton alpestris*). It was soon shown that the feeding of thyroid substance from other mammals than the horse is equally effective and indeed that the metamorphosis-inducing agent is also present in the thyroid glands of fishes, amphibians, reptiles, and birds. The literature on this subject has been reviewed by Uhlenhuth (1921) and by Schneider (1939) and indicates clearly that the thyroids of all vertebrates normally contain a substance which causes a hastening of metamorphic processes when fed to amphibian larvae. Administration of the thyroid substance by grafting, implantation under the skin, or injection of extracts also proved effective.

This being the case it was natural to suppose that in the normal development of the frog or newt the transformation from larva to adult is brought about through secretory activity of the animal's own thyroid. Proof of this hypothesis was soon forthcoming. Allen (1916) and Hoskins and Hoskins (1917) independently devised methods for surgical removal of the anlage of the thyroid gland in early larval stages and showed that animals lacking the thyroid fail to metamorphose although they are able to grow normally. Such larvae, since they continue to grow long after unoperated controls have transformed into adults, may become quite gigantic in size. Allen (1917a) and Schulze (1922) further showed that these giant tadpoles may at any time be induced to metamorphose by feeding with thyroid substance.

Meanwhile an independent line of investigation was leading to an understanding of the chemical nature of the active principle of the thyroid. It had long been known through the work of Baumann, Oswald, and others that an important constituent of the gland is iodine and that this element exists in the follicular colloid of the living thyroid in the form of a globulin, iodothyroglobulin. Two other iodine-containing compounds, diiodotyrosine and thyroxin, were also isolated from thyroid tissue by appropriate extraction methods. Thyroxin was obtained in crystalline form by Kendall in 1915, and its synthesis was accomplished by Harington and Barger in 1927. Various other iodine compounds having somewhat similar structural formulas, as well as analogous compounds containing other halogens, have been prepared, and many of them have been tested both for their effects on the metabolism of mammals and for their metamorphosis-inducing abilities. Morse (1914) showed that iodothyroglobulin is very effective in the induction of metamorphosis in the tadpole, and Kendall (1919) demonstrated the still greater potency of thyroxin. The latter substance has since been most extensively used in experiments where accurately controlled dosages of a strong metamorphosis-inducing agent are desired. Various related compounds such as iodothyrin and diiodotyrosine were also found to cause precocious metamorphosis of amphibian larvae, although they were less effective than thyroxin.

Since high iodine content is so peculiarly a characteristic of thyroid substance and of the active compounds extracted from it, the idea was advanced that iodine compounds other than those occurring in the thyroid gland might also affect metamorphosis to some degree. This proved to be the case, for it was shown that various complex iodine-containing substances, such as iodoserum-albumin, iodoserumglobulin, and iodocasein are

able to hasten metamorphosis although the concentrations required are much higher than are needed in the case of thyroxin or of iodothyroglobulin.

Romeis (1916), however, in testing various thyroid fractions, found that effects could be obtained from protein-free extracts and this led to successful experiments with still simpler iodine compounds such as iodoform, potassium iodide, and sodium iodide. In fact, elemental iodine itself proved effective in causing metamorphosis in thyroidectomized animals either when fed, implanted under the skin, injected in solution, or simply dissolved in the water in which the larvae are kept. On the other hand, experiments with other halogens such as bromine, and with organic compounds of bromine, like dibromtyrosine, showed that these substances do not affect metamorphosis. (See the review of Allen 1929.)

In view of these findings, Swingle (1918a) suggested that iodine is really the active principle of the thyroid gland and that the thyroid, rather than elaborating a true hormone, chiefly functions in extracting iodine from the blood and storing it, this stored iodine then being made available to the organism when needed. Such an hypothesis seemed to be supported by experiments in which pathological thyroid tissue of various types was fed to amphibian larvae (Graham, 1916; Abderhalden, 1919; Abelin, 1927; Welti and Roth, 1946), for the general result of such work indicated that while there is no parallelism between the amount of colloid present in a goiterous gland and its effect on metamorphosis, there is often a good correlation between the iodine content and the metamorphosis-inducing ability. A similar correlation was reported for certain ovarial struma containing large amounts of iodine (Plaut, 1931). Differences in iodine content probably also account for the different results obtained by Dessy (1930) from feeding thyroid glands of older and younger animals to tadpoles. It appears, however, in the light of recent biochemical studies, that the effectiveness of iodine and various iodine compounds in inducing metamorphosis in thyroidectomized amphibian larvae does not mean, as was earlier believed, that the complex organic molecule thyroxin is not necessary to bring about the tissue responses. It has now been demonstrated that thyroxin is formed in vitro by the iodination of proteins (Reineke, 1949), and it seems clear that when thyroidectomized tadpoles respond to the administration of inorganic iodine or simple iodine compounds they do so because the iodine taken into the body is readily fixed by the tyrosine available in the tissues, and active organic compounds such as diiodotyrosine and thyroxin are formed. In untreated thyroidectomized tadpoles the same reaction doubtless occurs with the small quantities of iodine which are taken in with the food and water, but the amount of thyroxin formed in the tissues in this case is insufficient to induce metamorphic changes. The work of Gudernatsch and Hoffman also tends toward this conclusion, for they found that tadpoles given various amino acids along with low concentrations of iodine showed increased rates of development, and that the degree of effectiveness differed depending on the amino acid used, tyrosine and iodine being the most effective combination (Hoffman and Gudernatsch, 1933). We may conclude that in all likelihood the metamorphic changes which occur in the larval tissues always take place under a stimulus from a complex thyroid-hormone, probably thyroxin, even in animals which lack a thyroid gland and regardless of the form in which iodine is made available to the animal. The iodine is important of course, since it is an indispensable constituent of the thyroid hormone, and it has been shown that even tadpoles with intact thyroids are not able to metamorphose if they are raised in an environment and fed on a diet which furnishes an insufficient amount of iodine (Lynn and Brambel, 1935; Metcalf and Creaser, 1937).

It should be noted that certain iodine compounds have been found ineffective in the induction of metamorphosis. Thus Swingle (1919) obtained no effects with potassium iodate, and Brandt (1937) was unable to get any response with a commercial protein preparation containing both iodine and bromine. Possibly in these cases the chemical structure is such that the iodine is not readily liberated.

B. Relation between thyroid activity and metamorphosis

With the discovery that thyroid administration can cause precocious metamorphosis a number of workers undertook detailed studies of the structure of the thyroid gland before, during, and after metamorphosis in attempts to correlate phases of activity of the gland with the metamorphic changes. Allen (1919), making gross measurements of thyroid glands of toad larvae dissected out at various stages of development, reported a

gradual increase in size of the thyroids during the early phases of metamorphosis, but a cessation of growth and an actual diminution in size of the glands when metamorphosis is most active. This observation he considered as an indication that the colloid stored in the gland is discharged at this time. Shortly after this, Mayerowna (1922) described the histological picture presented by the thyroid in tadpoles of *Rana esculenta*. In early stages the follicular epithelium was flat and the follicles were filled with an acidophilic colloid; with the onset of metamorphosis the epithelium increased in height, and the colloid became more fluid and exhibited chromophobe droplets. Later work by Sklower (1925), Hirschlerowa (1928), Etkin (1936a, b), Clements (1932), Aleschin (1936), Gasche (1939), D'Angelo and Charipper (1939), and D'Angelo (1941) has provided a quite complete picture of the changes in the thyroid which accompany normal metamorphosis in ordinary anurans, such as *Rana*, *Bufo*, and *Hyla*. Although the details differ somewhat in these different forms, there is general agreement that the gland shows increased activity either before the onset of metamorphosis or just as the first metamorphic changes appear. As metamorphosis proceeds, the thyroid activity, as evidenced by increased height of the follicular epithelium and by the appearance of intracellular and intrafollicular vacuoles, increases greatly and reaches a maximum near the time when the tail is undergoing rapid resorption. After this there is a gradual decrease in the height of the epithelium, and intracellular vacuoles become scarce. Some workers have reported that at the climax of metamorphosis the amount of colloid in the follicles decreases rapidly, so that the follicles become collapsed (Sklower, 1925; Hirschlerowa, 1928; Clements, 1932; D'Angelo and Charipper, 1939). Others, however, have found no such distinct stage of follicular evacuation (Etkin, 1936a).

Certain atypical anurans which have no true metamorphosis but instead lay terrestrial eggs and develop directly into small frogs are of special interest in this connection. Study of the development of the thyroid in one such form, the West Indian tree-toad *Eleutherodactylus* (Lynn, 1936), reveals that the gland shows evidence of precocious activity but no marked stage of either colloid storage or colloid release. Presumably the hormone secreted is released from the gland almost as quickly as it is formed, and plays a part in the telescoping of the larval stages which is characteristic of the embryonic development of this animal (Lynn, 1942). A similar situation obtains in the thyroid of *Arthroleptella*, a South African anuran with a somewhat similar life history (Brink, 1936, 1939).

In the gymnophionan *Ichthyophis glutinosus*, the larva goes through two metamorphoses. The first occurs at the time of hatching and involves resorption of the gills, whereas the second is characterized by cornification of the skin, closure of the gill slits, and loss of the dorsal crest. Klumpp and Eggert (1934) have shown that the thyroid shows signs of increased secretory activity in connection with the second metamorphic process only.

In an effort to establish a quantitative basis for judging the activity of the thyroid, Etkin (1930) studied the changes in cell number and in colloid volume in serially sectioned glands throughout metamorphosis in *Rana pipiens*. Both of these features were found to show marked increases, particularly during the period when the hind legs are growing rapidly. Moreover, the ratio of cell number to colloid volume is greatly increased during this time, but remains constant after the period of tail resorption. In a later, more detailed study (Etkin, 1936a), the relative volumes of the epithelium and colloid and the relation of these to total body weight were investigated in several species of *Rana* and in *Pseudacris triseriata*. It was shown that the thyroid first exhibits increased growth and activity at the beginning of rapid hind limb growth and that it reaches a peak of activity at the time when the fore limbs emerge. There is no evidence of a quick simultaneous release of colloid from the follicles, but a gradual regression in thyroid activity occurs late in metamorphosis. Etkin concluded that there is a rising concentration of thyroid hormone in the blood during metamorphosis and that the pattern of metamorphic events is determined by the pattern of increasing thyroid activity. Morita (1932) carried out a similar study of thyroid size and epithelium-colloid ratio at various stages in a Japanese species of *Bufo*, and obtained essentially the same results. Woitkewitsch (1937a) has reported a rise in epithelium-colloid ratio during metamorphosis in *Rana temporaria* but he maintained that his data give evidence of rapid colloid evacuation during the period of tail resorption.

The most detailed histological studies of the normal urodele thyroid are those of Uhlenhuth

and his coworkers (Uhlenhuth, 1925a, b, 1927, 1928, 1929, 1934; Uhlenhuth and Karns, 1928; Uhlenhuth, Schenthal et al, 1945; Algire and Uhlenhuth, 1944). These investigations include histological, cytological, and biometric studies of the thyroid in *Ambystoma* and *Triturus* at various stages in the life history, and many of these details have been considered in an earlier section of this paper. With respect to metamorphosis, it was found that the thyroid activity increases during this time just as in the Anura, but it appears that a much more marked release of colloid from the thyroid follicles occurs in the urodeles. The studies of Hirsch (1928) on *Triton* and of Grant (1931b) on *Ambystoma* also support this conclusion.

It is noteworthy that the thyroid glands of animals undergoing thyroid treatment show clear histological evidences of decreased activity. It appears that when the hormone is supplied to the tissues from external sources the animal's own thyroid ceases to function, probably because of a decreased output of thyrotrophic hormone from the pituitary (Mayerowna, 1922; Etkin, 1935a; Brink, 1936).

The question of when the thyroid first begins the accumulation of iodine has been attacked by administration of radioactive iodine by Gorbman and Evans (1941). They have found that, in *Hyla regilla*, storage of iodine occurs very shortly after the follicles are formed, while their cells are still laden with yolk. There is also evidence that the stored iodine is already in organic linkage, probably as thyroglobulin.

C. Detailed analyses of thyroid control of metamorphic events

It has been mentioned earlier that a rather detailed knowledge of the morphological and physiological changes which occur at metamorphosis was already available long before the discovery of the role of the thyroid in inducing these changes. The transformation is more striking in the Anura than it is in urodeles, but in both groups many important alterations occur in nearly every organ system of the body. The frog tadpole before the onset of metamorphosis is an aquatic animal with well-developed gills, a long flattened tail, lidless eyes and, in adaptation to its vegetarian habits, horny rasping teeth and a long coiled intestine. The adult frog, on the other hand, is a terrestrial lung-breathing animal with no tail, with well-developed limbs, and with carnivorous habits. During the transformation from one to the other, therefore, many larval organs such as gills, tail, and horny teeth disappear, while adult structures such as limbs, lungs, and eyelids rapidly develop. Moreover, certain structures of the larva which persist into the adult undergo rather extensive alterations. The skin thickens, becomes more glandular, and attains an outer cornified layer, the intestine decreases in length, the visceral arches are modified to form the hyoid apparatus, and the brain becomes more highly differentiated. Detailed analyses of many of these changes during normal metamorphosis and of the ways in which they are influenced by throidectomy and by thyroid administration have occupied the attention of a number of investigators.

Growth of the hind limbs in the Anura, since it is one of the most obvious early signs of metamorphosis, was noted as a criterion of thyroid activity in most of the early work on the subject. Allen (1925) studied the effects of thyroidectomy upon hind limb growth in *Bufo* and *Rana* and called attention to the important fact that in different amphibians there are differences in the degree to which the limbs will grow in the absence of thyroid stimulation. In *Bufo* the hind limbs of thyroidectomized larvae may reach a length of 8 mm., while in *Rana* they remain small buds. The growth in length of the hind limbs during normal metamorphosis has been studied in detail by Etkin (1932) for several species of *Rana* and proves to fit a sigmoid curve, the period of rapid growth occurring during the early stages of metamorphosis, and a considerably slower rate being characteristic of the later phases when the tail is being resorbed. Bower (1938) found the same type of growth curve for the limbs of *Rana sylvatica* during both normal and induced metamorphosis. Irichimowitsch (1936) advanced the idea that these differences in "growth energy" at different times are related to differences in the processes of histogenesis which are occurring in the limb, the early period of rapid growth being associated with differentiation and chondrification of skeletal parts and the period of decreased growth being characterized by increase in muscle tissue, beginning of ossification, and differentiation of skin structure. He called attention, however, to the fact that in induced metamorphosis the sequence of these changes is disarranged.

Tail resorption, another obvious external feature

of anuran metamorphosis, has been very extensively investigated. Barfurth (1887) proposed the hypothesis that tail resorption results from the fact that the rapid growth of the urostyle during metamorphosis causes pressure on the blood vessels at the base of the tail and gradually reduces the vascular supply until atrophy occurs. This view was supported by Bataillon (1891), who suggested that the reduced blood supply would cause an accumulation of metabolites in the tissues and that autolysis would follow the resulting acidosis. That Barfurth's hypothesis is untenable was shown by Helff (1926c, 1930), for ligation of the caudal artery results in no acceleration of tail atrophy, and extirpation of the anlage of the urostyle does not prevent tail resorption. It has also been demonstrated that tails transplanted to unusual positions where they are not in normal relations with the urostyle still degenerate concurrently with the host's tail (Fukai, 1934). Moreover, Reis (1930) found that tail skin transplanted to the back undergoes histolysis during metamorphosis, while skin of the back transplanted to the tail does not. Helff and Clausen (1929) carried out reciprocal transplants of tail and back muscle with similar results. Schwind (1933) transplanted optic vesicles to the tail at the tail-bud stage and found that these grafted eyes were not resorbed at the time of metamorphosis but slowly moved in and came to lie in the sacral region. It is thus apparent that the atrophy of tail tissues is not due to histolytic influences peculiar to the tail but to more generalized factors, and that the tissues of the tail have a differential susceptibility to these influences. In fact, Clausen (1930) has adduced some evidence which indicates that there is a gradient of susceptibility within the tail itself; for skin and muscle grafts taken from anterior regions of the tail and transplanted to the back undergo more rapid histolysis at metamorphosis than do those taken from more posterior levels. The difference in behavior of trunk and tail muscle at metamorphosis is determined at a quite early stage, inasmuch as Geigy (1937, 1941) has shown that myotomes of the tail transplanted to the trunk at the neurula stage are resorbed at metamorphosis simultaneously with the host's tail while trunk myotomes transplanted to the tail region are not resorbed. That there is a fundamental difference between the response of anuran and urodele tissues was shown by Nakamura (1937), who made reciprocal transplants of tail-buds between *Rana* and the salamander *Hynobius*. At the time of metamorphosis the anuran tails transplanted to salamanders underwent resorption, while urodele tails transplanted to frogs exhibited no atrophic changes. Concerning the nature of the histolytic agents which induce tail resorption, Helff suggested that a general lowering of the pH of the blood may be the chief factor which activates autolytic enzymes in the tail tissues, and he later demonstrated (Helff, 1932) that such a drop in blood pH does occur during metamorphosis. Aleschin (1935a, b), analyzing the histological changes during tail resorption in *Rana*, *Bufo*, and *Pelobates*, stated that the phenomena observed present the characteristics of an inflammatory reaction, and maintained that local acidosis in the tail tissues causes dissolution of the connective tissue stroma and thus plays an important part in the involution.

Beginning with the work of Ratner (1891), considerable attention has been given to the gross and histological changes which occur in the digestive tract during metamorphosis. These include shortening of the tract as a whole, histolysis and subsequent regeneration of much of the intestinal mucosa, and great increase in thickness of the muscular layer of the stomach. The earlier workers considered the type of food eaten as the causative factor in intestinal atrophy, but Swingle (1918a) showed that precocious intestinal involution is one of the features produced by thyroid treatment, and Sembrat (1924) demonstrated that transplants of intestinal tissue undergo metamorphic changes concurrently with the host intestine regardless of the age of the transplant. Detailed accounts of the histological changes in the intestine during normal metamorphosis have been given by Kuntz (1924), Liu and Li (1930), Janes (1935), and Iwane (1935); and Lim (1920) and Kaywin (1936) have described the histology and cytology of the digestive tract in tadpoles undergoing accelerated metamorphosis. The latter author found clear-cut changes in the Golgi apparatus in the epithelial cells and proposed the use of the Golgi as a criterion for following microscopically the course of metamorphosis in thyroid treated larvae. Changes in the liver and gall-bladder resulting from thyroid administration have recently been studied by Doetsch (1943), while Janes (1937) has investigated the effects of thyroid treatment upon the pancreas.

Another metamorphic feature which has attracted special interest is the perforation which

appears in the operculum to permit emergence of the fore-limb. Since the fore-limbs originate inside the opercular cavity as small buds and later grow rapidly, it was suggested that pressure of the growing limb upon the overlying operculum acts as a "formative stimulus" which induces perforation at the point of contact. However, Braus (1906) showed that when the forelimb anlage is removed so that a limb never forms, a perforation still appears at the usual stage in metamorphosis. He therefore concluded that the opening of the opercular skin occurs as a self-differentiating process, and the appearance of the opening at just the proper time and place to permit the passage of the fore-limb was widely cited as a particularly striking example of "harmony of independent processes." By means of transplantation and extirpation operations on several American species of *Rana*, Helff (1926a) was able to elucidate the matter much more completely. He found that the direct stimulus which brings about opercular perforation in these frogs is the presence of atrophying gill tissue within the opercular chamber. Since atrophy of the gills and growth of the fore-limbs are both processes which are dependent upon thyroid function, the opercular perforation does occur at the time of fore-limb growth. According to this concept, however, the perforation itself is not directly caused by thyroid hormone but is simply one reaction in a chain which is set in motion by the thyroid. This relationship was confirmed by the work of Van der Jagt (1929) and Fukai (1935). Weber (1931), however, carried out experiments on removal of fore-limb anlagen by electrocautery in *Bombinator* and in *Rana temporaria* and found that in some cases no perforation of the operculum occurred. He has maintained that whether or not the perforation appears depends upon whether cutaneous glands of the skin of the limb are completely eliminated. If any cutaneous glands are present in the opercular cavity then a perforation is formed. Blacher, Liosner, and Woronzowa (1934), working with reciprocal skin transplants between the opercular region and the body in *Rana temporaria* and *R. ridibunda*, interpreted their findings as demonstrating a self-degenerative potentiality specific in the skin of the opercular region. Alphonse and Baumann (1935a) maintained that the necrosis of opercular tissue is initiated because the blood vessels which supply this region degenerate at the time of metamorphosis. In view of these conflicting conclusions, Helff (1939) undertook an extensive series of experiments with *Rana temporaria* and *Bufo bufo*. His results indicated that different species of anurans differ considerably in the mechanism by which opercular perforation occurs, and that no one explanation can be given which will apply to all. In some species a particular area of the operculum does seem to possess self-degenerative potentialities. Histolytic influences emanating from the degenerating gills also play a part, and the cutaneous glands of the fore-limb may be an additional influence. Pressure exerted by the growing fore-limb constitutes still a fourth stimulus to perforation. In different anurans one or another of these may be the chief factor, but Helff concluded that in some species two or three different influences are effective, so that the opercular perforation is doubly or triply "assured." The recent work of Hama (1942) on the Japanese toad *Bufo vulgaris* gives evidence of "double assurance" for opercular perforation in this species.

The development of the tympanic membrane at the time of metamorphosis is another feature which has been subjected to detailed analysis by Helff (1928, 1937, 1940). The transformation of the integument covering the presumptive ear region into the characteristic structure of the tympanic membrane was found to be dependent upon inductive influences from the underlying annular tympanic cartilage. Early extirpation of this cartilage prevents membrane formation, and transplantation of the developing cartilage beneath the skin of the side or back results in the development of a typical tympanic membrane in these regions. That this inductive capacity is a remarkably strong one is evidenced by the fact that fully differentiated integumentary structures (dermal plicae) will transform into tympanic membrane when transplanted above the annular cartilage. Hyaline cartilages other than the annular cartilage have the ability to induce membrane formation to some degree, and dead annular cartilage also has a certain degree of effectiveness. Since it is necessary that the cartilage be in actual contact with the skin in order that the inductive effect be evidenced, Helff concluded that the influence is probably chemical in nature.

Characteristic pigmentary changes occur in the skin of both anurans and urodeles at metamorphosis. Weigl (1913) and Uhlenhuth (1917) early showed that these changes are dependent upon thyroid function, since skin grafts always show the transformation at the time when the host

undergoes metamorphosis, regardless of the age of the graft. In this way, in some of Uhlenhuth's experiments, different pieces of skin from the same animal were made to metamorphose at very different times, ranging from seven days to five months. Changes in the pigment pattern in the iris of the eye were also shown to occur in relation to metamorphosis in the same way. The histological changes which occur in the epidermal cells at metamorphosis were investigated by Speidel (1926) and Woronzowa and Liosner (1936) and were shown to occur following administration of thyroid extract. These metamorphic changes in the skin have been induced in small localized regions in salamander larvae by subcutaneous implantation of pieces of agar impregnated with thyroxin (Hartwig, 1940) and in *Rana* by implants of thyroid glands containing radioactive iodine (Kaltenbach, 1950). Alphonse and Baumann (1934) have maintained, however, that the skin of *Bufo* larvae does not respond if the concentration of thyroxin is beyond a certain optimum. Observations on metamorphic changes in skin transplants were used by Reis as a means of elucidating some problems relating to neoteny which will be discussed later. Barden (1943) has studied the changes in the pigmentation of the iris at metamorphosis by heteroplastic transplantation of optic vesicles in several species of *Ambystoma* and *Triturus*.

Various other metamorphic features to which special attention has been directed can be mentioned only briefly. The differentiation of the anuran tongue during metamorphosis has been fully described by Helff and Mellicker (1941), and the transplantation experiments of Helff (1929) indicate that the changes in the tongue are directly dependent upon thyroid stimulus. A similar conclusion was reached in work on the differentiation of the dermal plicae (Helff and Stark, 1941). Terry (1918) showed that ossification of the vertebrae does not occur in thyroidectomized tadpoles, and Schreiber (1932) has presented evidence that the thyroid hormone controls the course of endochondral ossification but does not influence perichondral bone formation. The course of ossification in neotenous and metamorphosed axolotls has been very fully worked out by Keller (1946). Histological changes in muscle tissue, skin, connective tissues, and nervous system after thyroxin administration have been described by Bredt (1933). Allen (1924) showed that the brains of thyroidectomized tadpoles fail to attain the characteristic differentiations seen in metamorphosed specimens, and Cooksey (1922) found that thyroid-fed larvae exhibit precocious differentiation of the brain. Kollros (1942, 1943a, b), in a series of studies on the corneal reflex in *Rana*, has shown that this reflex is controlled by a center in the brain which is self-differentiating but which requires the supplementary action of thyroid hormone before it becomes fully functional. In urodeles, molting is a metamorphic feature for which thyroid control has been clearly demonstrated (Adams, Kuder and Richards, 1932). It is of special interest that the differentiation of the gonads does not seem to be under thyroid control. The testes and ovaries of thyroidectomized tadpoles form mature gametes despite the fact that the animal as a whole retains the immature body form (Allen, 1917b; Hoskins and Hoskins, 1919; Krichel, 1931); and conversely the gonads of animals precociously metamorphosed by thyroid treatment show no acceleration of development (Swingle, 1918b). This is significant in relation to the occurrence of sexually mature "larvae" (neoteny) in nature.

D. The sequence and spacing of metamorphic events

Although all the processes discussed above are characteristic features of metamorphosis and have been shown to be either directly or indirectly induced by thyroid activity, it is clear that they do not all go on simultaneously; some metamorphic changes occur early while others appear only much later. Thus the events of metamorphosis take place in a definite chronological order, and it is possible to divide the process into various steps or stages and to designate criteria by which one can judge how far metamorphosis has proceeded in any given specimen. Surprisingly, a really thorough analysis of the metamorphic process from this point of view was not made until Etkin's (1932, 1935a) careful studies of the normal "metamorphic pattern" in *Rana palustris*, *R. clamitans*, and *R. catesbiana*. Using features which are easily observable externally, Etkin described the events of normal metamorphosis as occurring in the following order: 1) beginning of reduction of the anal canal piece; 2) completion of resorption of the anal canal piece; 3) appearance of the opercular perforation for emergence of the forelimb; 4) forelimb emergence; 5) reduction in size of the tadpole lips and loss of horny teeth; 6) loss of horny beaks; 7) beginning of rapid resorption of tail fin; 8) com-

pletion of tail fin resorption; 9) reduction of tail to a knob; 10) completion of widening of the mouth. The period of resorption of the anal canal piece was designated the "prometamorphic" period, while the succeeding events were spoken of as constituting the "metamorphic climax." Etkin demonstrated clearly that in normal metamorphosis the changes "not only follow in a set order, but . . . are so spaced as to allow adequate time for the expression of each." The sequence and the spacing thus make up a normal "pattern" of metamorphosis, a pattern which is a constant feature of the transformation of all the members of any given species. Schreiber (1937) has defined the metamorphic pattern for *Bufo;* and in urodeles a similar chronology has been worked out for *Eurycea*, *Triturus*, and *Ambystoma* by Wilder (1925) and by Grant (1930a, b).

It is necessary to note, however, that this normal metamorphic pattern is not produced when larvae are induced to metamorphose precociously. Indeed, in some of the earliest studies of experimentally induced metamorphosis attention was called to the fact that the transformation which is brought about by administration of thyroid substance or iodine compounds often differs markedly from the normal process. This is particularly striking when relatively large doses of the metamorphosing agent are used, for under such circumstances the changes which should come late in metamorphosis occur so precociously that they may be completed before some of the first stages are well begun. Thus the tail may be completely resorbed when the hind limbs are still small buds. Such disharmonious metamorphic changes result in the formation of very abnormal animals which are unable to survive. With extremely low concentrations of the metamorphosing agent, on the other hand, some changes may be accelerated, but later features are so little affected that the usual time relations between successive events are greatly distorted. Even if one confines attention to a single organ, disharmonies resulting from induced metamorphosis may be found. For example, Romano (1936) reported that in thyroxin-treated tadpoles the cornea undergoes metamorphosis so rapidly that it attains the adult condition at a time when the lens is still larval, an inversion of the normal chronology, while Schreiber (1934b), and Schreiber and Koch (1941) found disharmonies among the parts of the retina in thyroid-accelerated animals.

Hypotheses to explain this disharmony grew out of early experiments upon the effects of different concentrations of metamorphosis-inducing agents. At first the interest in such studies centered in attempts to ascertain the minimum dose of thyroxin, iodine, or other agent which would elicit a response. Later, however, attention was given to the comparative effects of different doses administered at various times during larval development. Romeis (1923), working with tadpoles raised in graded thyroxin concentrations, was apparently the first to state clearly that different organs may behave differently toward the same dose of the metamorphosing agent, for he noted that with very low concentrations some metamorphic changes occurred while others failed to make an appearance, a fact which was confirmed by Alphonse and Baumann (1935b). Blacher (1928) extended this by the finding that after a brief exposure of *Rana* tadpoles to thyroid treatment certain structures are more definitely affected than others. He therefore proposed the hypothesis that different parts have different thresholds of sensitivity, those having the lowest thresholds being the ones which appear early in normal metamorphosis, and those with higher thresholds appearing later. Allen (1932) also reported differences in response of different tissues when tadpoles of *Bufo halophilus* were immersed in various thyroxine concentrations and further pointed out that the response varies in relation to the duration of treatment.

As has been noted, Etkin's (1930, 1932) studies of the growth of the thyroid gland and the correlated body changes during normal metamorphosis had indicated that the gland becomes increasingly active during early metamorphosis, and had suggested that the normal spacing of metamorphic events could be related to a gradual increase in concentration of thyroid hormone in the blood. Experiments undertaken to test this idea (Etkin, 1935a) by analyzing in detail the metamorphosis of tadpoles raised in various concentrations of thyroxin served to confirm the hypothesis. For it was shown that, while no single concentration is capable of inducing a normal metamorphic pattern, such a pattern can be obtained if one begins by treating young tadpoles with low concentrations of thyroxin and later changes gradually to higher dosage levels. The exact concentrations to be used and the times when increases in level are to be made must be determined empirically, but careful observation of the individual specimen

and proper manipulation of the treatment can result in a normal metamorphic pattern in a thyroidectomized animal. On the basis of his experiments Etkin concluded that the sequence of events is not controlled by the metamorphosis-inducing agent but is inherent in the tissues. The time intervals between events, on the other hand, are dependent upon the activating substance, normal spacing depending upon a gradually increasing concentration of this substance. The evidence indicates that before metamorphosis a very low level of thyroid hormone is probably necessary to prepare the hind limbs for their period of rapid growth. This growth is then initiated in response to a rise in thyroid activity, a rise which, however, must extend only so far as to allow a maximal rate of hind limb growth without precipitating the changes of metamorphic climax. Later, after the hind limbs have attained some degree of development, the climax phenomena appear and proceed rapidly because of a still greater increase in thyroid activity and a resulting relatively high concentration of thyroid hormone in the tissues. As Etkin has pointed out, "the significant feature of the interpretation offered is that it explains a specific developmental time pattern by a purely quantitative mechanism, a variation in hormone concentration."

A somewhat similar explanation of the chronology of metamorphic events was proposed by Schreiber (1934a) in a theoretical paper which is largely concerned with explaining the disharmonies that are observed in induced metamorphosis. Schreiber's theory is based upon the concept earlier proposed by Blacher and others that different features of metamorphosis have different thresholds of response to the thyroid hormone. Schreiber cited Etkin's (1930) study of the growth of the thyroid gland as indicating that a gradual increase in thyroid activity occurs during metamorphosis, and he concluded that the normal sequence of events is determined by the fact that the changes which have low thresholds of response occur first and are followed successively by the changes with higher thresholds, as the hormone concentration reaches higher levels. Schreiber's theory thus accounts for both the normal sequence and the normal spacing of events on the basis of differing threshold and a gradual increase in thyroid activity. When precocious metamorphosis is induced by administration of a moderately high dosage of thyroid material, then, according to Schreiber's interpretation, all events are initiated simultaneously and striking disharmonies naturally result. Thus in normal metamorphosis certain changes, e.g., rapid hind limb growth, should begin early under the influence of low thyroid concentrations and should then proceed for some time before the thyroid activity builds up to such a level as to inaugurate later changes, such as tail resorption. In induced metamorphosis, since both begin at the same time, it is the events which have low thresholds that seem retarded, from not having sufficient time to attain completion before the other changes have occurred. Schreiber felt that all of the reported cases of disharmonies produced by thyroid administration are explainable on this basis. A similar concept has been advanced more recently by Gasche (1940).

It must be pointed out that Etkin's interpretation, while it is somewhat similar to Schreiber's, differs in the important respect that it is not based upon an idea of differing thresholds of response. Indeed, Etkin's experiments with various thyroxin concentrations indicated that all of the events of metamorphosis do respond even to extremely low concentrations. Moreover, with high concentrations, although all of the events occur rapidly, they are still initiated in the normal sequence. A point which is of fundamental significance, however, is that the rate of response is a function of the concentration of the metamorphosing agent so that in low concentrations all changes occur slowly while in high concentrations all occur rapidly. In the normal tadpole during prometamorphosis the thyroid concentration is low and although all the tissues are activated, only those which respond by fairly rapid rates of growth show readily detectable changes. Since the increase in thyroid concentration is gradual, these early changes go on for some time before the responses in other tissues are rapid enough to attract notice. When, however, the thyroid concentration has become high enough to raise the metamorphic rate sufficiently, these later changes become very striking, since they now occur with great rapidity. It is of interest that Etkin also found evidence of a rather sudden drop in the activity of the thyroid at the end of metamorphosis, and he suggested that the cessation of metamorphic change in the tissues when transformation has been completed may be related to the sudden lowering of the hormone concentration at this time.

It is clear that Etkin's hypothesis offers a logical

explanation both for the normal metamorphic pattern and for the disharmonies observed in the pattern of precociously induced metamorphosis. Since the theory is also supported by a considerable body of experimental evidence, it has now gained general acceptence (Allen, 1938; Bounhiol, 1942).

Thyroxin administration to very young larvae with external gills does not affect the time of appearance or rate of growth of the hind limbs (Alphonse and Baumann, 1933). It now appears that tadpole tissues first acquire their sensitivity to thyroxin at the time when the opercular membrane begins to form (Etkin, 1950). Animals exposed to treatment before this time show no metamorphic changes until they reach the stage of opercular formation. This is, of course, not to say that thyroxin administration at very early stages may not produce effects upon features which are not of a metamorphic nature. For example, Baumann (1936) reported that cleavage rate is increased in amphibian eggs exposed to thyroxin immediately after fertilization, and such eggs often give rise to exogastrulae or larvae showing spina bifida.

E. Theories of the mode of action of the thyroid secretion in metamorphosis

With the first recognition of the importance of the thyroid in metamorphosis, it was natural to attempt to relate this effect to the already well-recognized role of the thyroid in the control of metabolism. It was pointed out that many of the features of metamorphosis involve a rapid loss of tissue, and that this is also characteristic of the clinical picture presented by hyperthyroid cases. Some workers went so far as to suppose that the thyroid control of metamorphosis is exerted solely through its influence on metabolism and that there is no necessity for postulating any direct effect upon development.

Huxley (1922) presented a rather detailed theory based on this idea. His hypothesis rests upon the view that the typical amphibian life history may be regarded as a consecutive dimorphism somewhat comparable to the consecutive sex-dimorphism seen in protandric and protogynous hermaphrodites and that metamorphosis, like sex-reversal, is associated with changes in the balance between certain internal factors. The most important of these factors is the level of metabolic activity, which is under direct control by the thyroid. Huxley proposed that larval tissues are adapted to live at a low rate of metabolism, while adult tissues are adapted to a higher rate. When the metabolic level is raised beyond a certain threshold, the larval tissues can no longer maintain themselves in a functional state and they begin to break down. On the other hand the tissues characteristic of the adult, finding the new conditions more favorable to their function show an accelerated growth rate. Differences in the metamorphic responses of different tissues within the organism, as well as differences in responses of the same tissue in different species, are explained on the basis of inherent differences in the exact metabolic level to which the tissues are adapted. Some doubt was cast upon the idea of metabolic effects as an explanation for metamorphosis, however, when Kendall (1919) reported experiments with an acetyl derivative of thyroxin which had no effect upon basal metabolism in mammals and yet induced rapid metamorphosis of tadpoles, a result which was later confirmed by Swingle, Helff, and Zwemer (1924). Moreover, Cutting and Tainter (1933) found that administration of dinitrophenol to toad larvae does not bring about any acceleration of metamorphosis, although it does cause a definite increase in the metabolic rate. In this connection it should be noted that a number of authors have reported that there is an increased metabolic rate, as measured by oxygen intake or carbon dioxide output, in amphibian larvae during normal metamorphosis or in larvae treated with thyroid substance (Gayda, 1921a, b; Groebbels, 1922; Helff, 1926b; Bělehrádek and Huxley, 1927). Most of these workers, however, have expressed the belief that such a rise in metabolism is an accompaniment rather than a cause of metamorphosis. Moreover, some investigators have failed to find any indication of an increase in total metabolism during metamorphosis (Abelin and Scheinfinckel, 1923; Etkin, 1934); and there is reason to doubt that thyroid administration causes any increase in metabolic rate in adult amphibians (Drexler and von Issekutz, 1935). As a matter of fact, with increased knowledge of the variety and complexity of the changes which occur at metamorphosis an explanation of the phenomenon as a consequence of a general increase in metabolic activity seems hardly possible.

Another early general explanation for the metamorphic effects of thyroid hormone was based upon the hypothesis that the secretion causes an increased rate of cell division in certain organs,

while causing retrogressive changes in others. It is true that several studies have indicated that thyroid administration affects the mitotic rate in various tissues. Lim (1920) observed large numbers of mitotic figures in all of the layers of the digestive tract in thyroid-treated larvae, and Speidel (1929) found that the rate of cell division in the regenerating tail of the tadpole is increased by thyroid administration during the proliferative phase of regeneration. Champy (1922) maintained that the thyroid hormone causes a general increase in mitotic rate in those organs which are characteristic of terrestrial life, i.e., lungs, limbs, and intestine, but that it brings about regressive effects in parts characteristic of aquatic existence (horny beaks, tail, gills). He believed that when high doses of thyroid substance are given, the degenerative effects are stronger than those involving cell multiplication; while with low doses the reverse obtains.

A more recent attempt at a general explanation of the thyroid action in metamorphosis is that of Aleschin (1935b), who has maintained that during the development of the tadpole the thyroid gradually enlarges and attains a maximum secretory activity in early metamorphosis, but that it ceases its activity and goes into a resting phase before the beginning of tail resorption. During the secretory period the tissues become impregnated with thyroid hormone. When the concentration in the tissues attains a certain level, intracellular enzymes in the intestine and gills, which are most sensitive to the hormone, begin autolysis of these tissues. This in turn creates a state of acidosis in the entire organism. Moreover, since feeding ceases during transformation of the intestine, the organism begins to nourish itself at the expense of the tail tissue, the latter being also particularly sensitive to the histolyzing influence of the thyroid hormone and the general acidosis which now prevails. After this, the autolysis of tissues goes on automatically because of the accumulation of the acid products resulting from these processes themselves. Thus, once the degenerative changes of metamorphosis have begun, they continue, despite the fact that the thyroid is by this time in a resting condition. To account for the differentiative aspects of metamorphosis Aleschin had recourse to an entirely different mechanism and ascribed them to the influence of the growth hormone of the pituitary, which he assumed is increased concomitantly with the increase in thyrotrophic hormone that caused the original activity of the thyroid gland. Aleschin's bases for this hypothesis rest mainly upon his own observations on the histology and tissue acidity of the tail during involution (Aleschin, 1935a) and upon Helff's (1932) findings that blood acidity increases in metamorphosing tadpoles. He also recalled that Hoskins (1922) found evidence that metamorphosis, once begun, can be carried through in the absence of thyroid stimulus. Hoskins' experiments consisted in transplanting the thyroid anlage to the tail, allowing the animal to develop and go part way through metamorphosis, and then removing the tail with the contained graft. He reported that when this was done in animals which had well-developed hind-legs, most of them continued through metamorphosis although they now lacked a thyroid. However, in view of Etkin's (1935a) findings that thyroidectomized tadpoles raised in thyroxin solutions very promptly cease to show metamorphic changes when removed from the solutions, some further study of this matter is desirable. The idea that the autolysis of the tail provides the materials for growth of the limbs, a notion which is implied in Aleschin's theory, has been controverted by Irichimowitsch (1936), and Woitkewitsch (1937a), who have pointed out that, since the most active growth of the limbs begins before the onset of tail resorption, it is not possible to regard the two processes as being interdependent. It is clear that any real experimental support for Aleschin's hypothesis is still lacking and that the necessity for invoking the growth hormone of the pituitary to explain the differentiative phases of metamorphosis constitutes a serious weakness in the theory.

As a matter of fact, none of the aforementioned hypotheses has ever gained wide acceptance, for it is difficult to imagine that the diverse changes which occur at metamorphosis can be explained on the basis of any general physiological effect of the thyroid hormone. It seems preferable to suppose that the characteristic responses which different tissues give to the hormone result from factors inherent in the tissues themselves. The question of the origin of these different modes of response then becomes simply one aspect of the general problem of differentiation. This, the central problem of embryology, has been subjected to most intensive experimental investigation since the pioneering studies of Roux and Driesch, and although it is by no means solved, a great deal is now known about the factors involved in the develop-

ment of embryonic diversity. It is clear that the development of parts and tissues which differ in their constitutions and in their later fates is an epigenetic process. It occurs under the influence of inductors, "organizers," and field effects of various types, and in many cases it can be demonstrated that the future fates of parts are more or less definitely fixed at quite early stages (gastrula or earlier). Although most of the studies of the "determination" of parts and the effects of inductors, etc., deal with morphological features, every embryologist realizes that the changes which occur in the tissues involve physiological factors as well. It is therefore reasonable to consider that in the amphibians, during the embryonic differentiation of diverse morphological types of tissues, the tissues also become differentiated as to their characteristic physiological response to a metamorphosing agent. The diverse changes initiated at metamorphosis would then be determined just as much by the reacting tissues as by the substance inducing the changes. The differences in the characteristic responses of the tissues in diverse amphibian groups (anura, urodeles, perennibranchiates) could, on such an hypothesis, be based either upon genetic differences in tissue reactivity or upon genetic differences in the functioning of the endocrine complex. Such a view has been presented by Geigy (1941) in a theoretical paper based on his earlier transplantation experiments. Hadorn (1941) has analyzed insect metamorphosis on somewhat the same basis, and Needham's (1942, pp. 447–456) discussion of amphibian metamorphosis is also approached from this point of view.

F. Environmental factors affecting metamorphosis

Various environmental factors which influence metamorphic processes deserve some comment. The fact that increased temperature hastens the effect of thyroid treatment was early attested by the work of Terni (1919), and the histological observations of Adler (1916) on the thyroids of *Rana temporaria* larvae from localities having widely differing climatic conditions led him to suggest that prevailing temperatures may be important in determining whether the tadpole transforms during its first summer or over-winters in the larval state. He also pointed out the possibility that neoteny in amphibians may be associated with low temperature. Eggert (1934) drew similar conclusions from a histological study of the thyroids of larvae of *Molge alpestris* kept at different temperatures. However, the experiments of Belkin (1933), Tchepovetsky (1934), and Fosi (1935) have demonstrated that, while the metamorphosis of thyroid-treated axolotls or frogs can be hastened by increased temperature, a temperature increase alone will not suffice to induce metamorphosis. Huxley (1929) reported that at temperatures below 5° C. *R. temporaria* tadpoles fail to metamorphose even when given moderate doses of thyroid substance. The animals undergo a partial transformation but then cease to change, remaining in this intermediate condition for several weeks even when returned to room temperature. Huxley's explanation of this effect is that the thyroid treatment causes a compensatory reduction in the animal's own thyroid gland and that at low temperatures some of the administered thyroid substance is utilized in counteracting the low temperature effects. Under these conditions the amount of thyroid material available to produce metamorphosis is insufficient to bring about completion of the process and, since the animal's own gland is is now too reduced to effect the change, metamorphosis is halted when only partly complete. Huxley concluded from this experiment that in cold-blooded vertebrates the thyroid acts as a primitive temperature-buffer.

Another environmental factor which affects the action of the thyroid in inducing metamorphosis is the acidity of the medium in which the tadpoles live. Scheer and Berchtold (1926) reported that thyroid treatment has an increased toxicity when the acidity of the medium is increased. Rosen (1938) found that acidity or alkalinity, between pH 4.8 and 11.0, has no effect on the growth or metamorphosis of untreated tadpoles but that acidity accelerates and alkalinity retards the metamorphosing action of thyroxin. Marzulli's (1941) experiments confirmed those of Rosen but further demonstrated that when the thyroxin is administered by injection its effects are not dependent upon the pH of the culture medium. Marzulli also showed that the rate of respiratory metabolism is greater in tadpoles kept in an acid medium than in those kept in an alkaline medium. He therefore concluded that the greater effectiveness of thyroxin dissolved in an acid culture medium is due to a more rapid intake of the material under such conditions.

Zondek and Reiter (1923) reported that electrolytes such as $CaCl_2$ and KCl have accelerating effects upon the metamorphosing action of thy-

roxin, but Kosmin and Resnitschenko (1927) were unable to confirm these results. Abelin (1923) presented some evidence for an inhibiting effect of phosphate ion upon thyroxin activity. It seems probable that both the results of Zondek and Reiter and those of Abelin were due to changes in the pH of the medium rather than to any specific effects of the ions in question.

The amount of space available to the larvae, or the degree of crowding, are factors which strikingly affect the rate of growth (Bilski, 1921; Adolph, 1931a; Rugh, 1934); and the work of Adolph (1931b) and of Lynn and Edelman (1936) has indicated that the time of metamorphosis also varies in relation to the space factor. Adolph (1931b) suggested that the delay of metamorphosis which is seen under crowded conditions is mainly due to the decreased growth rate and concluded that body size is a tangible quantitative factor in the complex of conditions which regulates the onset of metamorphosis. In Etkin's (1935a) experiments, however, there was no indication of a difference in sensitivity to thyroxin treatment between large and small tadpoles of the same age. The delayed metamorphosis under crowded conditions is probably due therefore to delayed functioning of the thyroid rather than to any lack of tissue sensitivity in small animals.

Several authors have shown that x-radiation alters tadpole response to metamorphosing agents. Puckett (1937) found that larvae given sublethal doses of x-rays and subsequently fed with thyroid material go through the retrogressive changes of metamorphosis more quickly than do controls, but the differentiative changes fail to occur. Radiation of portions of the body, followed by thyroid feeding, results in effects confined to those parts receiving the x-rays. It appears that the effect of radiation is purely local and consists chiefly in an inhibition of cellular differentiation.

G. Effects of diet on metamorphosis

The effects of the type and amount of food consumed upon the growth of amphibian larvae have been extensively studied. The results of such investigations are not pertinent to the present review except in so far as they relate to the thyroid function and metamorphosis. Adolph (1931b) has suggested that many of the early experiments which showed effects of diet upon the time of metamorphosis really influenced the process only because they affected the body size of the animals. There are certain food substances, however, which do appear to have specific effects upon the course of metamorphosis. McCarrison (1921) presented evidence that tadpoles fed with a high fat diet are delayed in metamorphosis, and Kniebe (1920) showed that administration of oleic acid has the same effect. This may explain the results of Woitkewitsch (1935b), who found that thyroid grafts failed to induce metamorphosis when tissue from the uropygial gland of the young pigeon was implanted with the thyroid. Gudernatsch and Hoffman (1936) found that certain amino acids are of importance in promoting differentiative changes in tadpoles. Doetsch (1938) has given evidence that a vitamin poor diet causes a decreased growth rate and a delayed metamorphosis if fed during early larval life. He reported, however, that the feeding of such a diet during early metamorphosis causes an acceleration of the process due to an increased tissue sensitivity. Taniguchi (1930) has shown that certain vitamin B preparations cause some acceleration of metamorphic processes in several Japanese anurans. Vitamin A has been reported to antagonize the action of thyroid hormone in both anurans and urodeles (Fleischmann and Kann, 1937), but this has not been confirmed in the recent experiments of Klenner and Gennaro (1950).

Starvation of tadpoles may result in either retardation or acceleration of metamorphosis depending upon the time during development when feeding stops. Early inanition retards development, but starvation initiated at late stages causes precocious metamorphosis. D'Angelo, Gordon, and Charipper (1938) showed that the critical period of this effect is in the period of early hind limb growth (5–8 mm. hind-limb length in *R. sylvatica*). These authors later demonstrated (1941) that inanition at early stages results in extreme atrophy of the thyroid gland and failure of the pituitary to differentiate fully. The evidence indicates that it is the pituitary derangement which is fundamentally responsible for the metamorphic failure. The thyroids of animals subjected to inanition after the critical stage continue to show histological evidence of secretory activity for some time, and it is suggested that early metamorphosis in these specimens may result from a precocious and sudden burst of thyroid activity, possibly because of an increased sensitivity to the thyrotrophic hormone of the pituitary.

H. Relations of other endocrine glands to metamorphosis

1. Hypophysis

Adler (1914) was the first to demonstrate the close relationship between thyroid function and the hypophysis in amphibians. He showed that destruction of the hypophysis in the larva results in failure to metamorphose and that hypophysectomized larvae have thyroid glands which lack colloid. These findings have been confirmed and extended by the work of many investigators, and it is now well established that the hypophysis has a controlling influence upon thyroid activity. In the absence of the pituitary, the thyroid fails to attain its normal size and remains inactive, and metamorphosis is consequently inhibited. Administration of pituitary substance by injection to such inhibited larvae is rapidly followed by initiation of metamorphic changes. The pituitary effect is not a direct one, for pituitary administration to thyroidectomized larvae is entirely ineffectual (Schwartzbach and Uhlenhuth, 1928, 1933; Figge and Uhlenhuth, 1933); and it is clear that the pituitary substance acts through the induction of secretory activity and colloid release by the thyroid. The cytological changes produced in the thyroid by hypophysectomy have been fully described by Aleschin (1939).

By grafting various parts of the pituitary into hypophysectomized tadpoles, Allen (1921) showed that it is the anterior lobe of the gland which affects the thyroid activity; and later work has demonstrated that the thyroid-activating substance is confined to this portion of the pituitary. Subsequent development of various extraction methods has resulted in the preparation of quite potent thyroid-activating fractions from the anterior lobe (Uhlenhuth, 1937). It appears that the response of the thyroid to the thyrotrophic hormone is a quantitative one, directly proportional to the amount of hormone injected (Uhlenhuth, Schenthal, Thompson, and Zwilling, 1945). Investigations dealing with the chemical nature of the thyrotrophic hormone have been carried out almost exclusively upon mammals. For an account of these studies the reader is referred to the review of Albert (1949).

Attempts to ascertain whether the secretion of the thyroid-activating hormone can be ascribed to any specific cellular elements of the anterior lobe in amphibians have given somewhat contradictory results. Larson (1918), Clements (1932), and Schliefer (1935) were unable to find any changes in the structure or proportions of the various cell types during normal metamorphosis or under conditions of accelerated metamorphosis. Spaul and Howes (1930) concluded that the oxyphil cells are associated with thyrotrophic function in the ox, and Kerr (1939), finding an increase in these cells during metamorphosis in *R. temporaria* and *B. bufo*, maintained that this holds for the Amphibia also. Most other investigators of the amphibian pituitary, however, have felt that the evidence tends strongly to the conclusion that the basophil cells are concerned with the production of thyrotrophic hormone. Allen, Torreblanca, and Benjamin (1930), D'Angelo (1940), and Irichimowitsch (1941) found significant increases in the number of basophils in the anterior lobe in association with increased thyroid activity and metamorphic changes during normal development in various amphibians, and Grobstein (1938) observed vacuolation of the basophils following thyroidectomy in *Triturus*.

The development of the thyrotrophic function in the pituitary is independent of specific nervous stimulation, for heterotopic pituitary grafts made into hypophysectomized tadpoles at various stages readily induce metamorphic changes (Etkin, 1935b).

The potency of the thyrotrophic hormone shows seasonal variations (Keaty, 1942), and there is clear evidence that the thyrotrophins of different vertebrate groups are qualitatively different (Gorbman, 1946). Studies concerning the specificity of the thyrotrophic hormone have recently been reviewed by Adams (1946a). It is of interest that stasis (starved, non-metamorphosing) tadpoles show a marked sensitivity to this hormone and have therefore been suggested as test objects for thyrotrophic hormone assay (D'Angelo, Gordon, and Charipper, 1942; D'Angelo and Gordon, 1949, 1950).

Blount and Blount (1947) have adduced evidence for two distinct types of thyrotrophic activity in amphibians, one concerned with storage of colloid in the thyroid, the other concerned with colloid discharge. Such a dual mechanism may have important bearings upon the problem of neoteny, which is to be discussed below.

During the very early stages of the development of the pituitary in *Rana* a thyrotrophic effect is exerted which is apparently not hormonal but is of the nature of a field effect. Thyroid glands transplanted to a position very close to the pitui-

tary at this time show marked stimulation, and precocious metamorphosis is induced (Etkin, 1936c; Etkin and Lasky, 1938; Etkin and Huth, 1939). The stimulus is short-lived and it is questionable whether it is at all related to the thyrotrophic effects of the differentiated pituitary. It is, seemingly, an effect which would never come into play in normal development, since the normal locations of thyroid and pituitary are too far apart for any such stimulus to be exerted.

2. Thymus

In connection with Gudernatsch's (1912, 1914) early experiments on thyroid feeding, it was also reported that the feeding of thymus tissue to tadpoles causes accelerated growth and delayed metamorphosis. Uhlenhuth (1919) obtained similar effects with urodeles and concluded that the inhibition of metamorphosis was due to the absence from the thymus diet of some material required for proper development of the thyroid. Sklower (1927) maintained that, while thymus feeding does inhibit thyroid function in young tadpoles, it is without effect in older animals, a conclusion which has recently been supported by Mazzeschi (1940). On the other hand, Colosi (1932) reported that simultaneous feeding of thymus and thyroid is more effective in inducing metamorphosis than is thyroid feeding alone. It must be noted, however, that thymectomy has not been demonstrated to have any effect upon metamorphosis (Allen, 1920b), and thymus grafts have also proved ineffective (Woitkewitsch, 1935a).

Bounhiol (1942) has suggested that the contradictory reports concerning the effects of thymus feeding may be due to the frequent, though not invariable, presence of large amounts of fat in the gland, inasmuch as fat, according to the previously cited findings of McCarrison (1921) and others, would tend to inhibit metamorphosis.

3. Adrenal

Little is known of the relations between the secretion of the adrenal cortex and metamorphosis. Woitkewitsch (1937b) found that implantation of mammalian adrenal cortex in tadpoles causes increased growth but no acceleration of metamorphosis. Bock (1938), on the other hand, reported a definite increase in metamorphic rate of thyroxin-treated tadpoles when cortin is administered.

The secretion of the adrenal medulla, adrenalin, was reported to be effective in inducing metamorphic changes in the gills and skin of *Necturus* when administered in combination with thyroxin (Gutman, 1926). Neither thyroxin alone nor adrenalin alone produced these effects. Uhlenhuth, van Slyke, and Mech (1934) demonstrated that adrenalin also increases the effectiveness of the thyrotrophic hormone of the pituitary. Simultaneous administration of adrenalin and the thyrotrophic hormone to *Ambystoma tigrinum* larvae causes a much greater acceleration of metamorphosis than is produced by the thyrotrophic hormone alone. Geiringer (1938) found a similar synergism in the effect of adrenalin and thyroxin upon color change in *Hyla*.

4. Gonads

Although early studies on the feeding of gonad substance, administration of gonad extracts, and gonadectomy seemed to show no effects on metamorphosis, several recent investigations indicate that such effects may exist. Klöse (1941), in a detailed study of the results of castration in *Triton*, found an increased storage of colloid in the thyroid, particularly in males. Partial regeneration of the gonads reduced or nullified this effect. Roth (1947b) has maintained that testosterone is antagonistic to thyroxin action while the estrogens show no effect.

5. Pancreas

Aron (1928) demonstrated that the endocrine activity of the pancreas is influenced by the thyroid. The Islands of Langerhans increase in size and show decreased pigmentation during the early phases of metamorphosis, and the same changes are exhibited by the islet tissue of thyroxin-treated tadpoles. Glycogenic activity in the liver also begins with the onset of metamorphosis, and it is clear that the pancreas plays a controlling role in establishing this function (Aron, 1931). Thyroid administration thus indirectly affects liver function, the effect being intermediated by the pancreas. The importance of this relation has been emphasized by the work of Bilewicz (1938), for the glycogen reserves in the liver seem to be significant in the nourishment of the larva during the later phases of metamorphosis, when the changes occurring in the digestive tract prevent feeding. Hepatic glycogen reserves fall to 5 per cent of their former value during this time.

6. Parathyroids

Allen (1920a) reported that the parathyroid glands of thyroidectomized *Bufo* larvae exhibit marked hypertrophy but show no histological

peculiarities. Schulze (1921), however, was not able to demonstrate any effect of parathyroid feeding upon the metamorphic process.

I. The thyroid and neoteny

Although most amphibians have a larval period of fairly definite duration and then undergo a characteristic metamorphosis, it is well known that in certain urodele species some specimens may be found to retain the larval body form throughout life. Such animals reach sexual maturity and are able to reproduce, so that many generations may pass without a typical adult ever appearing. This phenomenon was first described by Dumeril for the American axolotl, *Ambystoma tigrinum*, and Kollman (1884) coined the term neoteny (prolonged youth) to designate the condition. It was noted that neoteny is commonly found in animals which inhabit lakes in high mountain regions, specimens of the same species living at lower altitudes exhibiting a normal metamorphosis. Early observers advanced the hypothesis that in such lakes the shores were steep and difficult to climb, so that the salamanders, being unable to emerge from the water, were forced to remain aquatic. It was supposed that if the animals were given an opportunity to leave the water or were forced out of the water by drying of the lake they would then transform. Dumeril failed in an attempt to demonstrate this experimentally, but Chauvin (1876) reported success in inducing young axolotls to metamorphose by gradual drying of the water in which they were kept. Boulenger (1913) and Huxley (1925) were unable to confirm Chauvin's results, however, and it seems likely that the larvae she studied belonged to one of the races of axolotls which readily metamorphose under laboratory conditions without treatment. Various other external factors, such as temperature, oxygen tension, and food supply, were suggested as possible factors in inducing neoteny in mountainous regions but little direct evidence was advanced to support these ideas. After the discovery of the role of the thyroid in metamorphosis a number of investigators showed that administration of thyroid substance, thyroxin, or various iodine compounds to young axolotls causes rapid metamorphosis. Administration of inorganic iodine gave conflicting results, but it was finally shown that this treatment is also effective, providing the iodine is implanted under the skin or in the peritoneal cavity so that rapid absorption is assured. The fact that the axolotl tissues are capable of reacting in a typical way to the influence of metamorphosing substances can also be demonstrated by the method of heteroplastic transplantation. Axolotl tail-buds transplanted to the flank of *Triturus* metamorphose concomitantly with the host tissues (Geigy, 1938).

Since it was now clear that axolotls respond to thyroid substance and iodine in the same way as do ordinary amphibians, experiments were undertaken to ascertain the basis for their failure to metamorphose in nature. Adler (1916), in an extensive study of both experimentally treated animals and neotenic specimens collected in nature, demonstrated that extremes of temperature cause characteristic changes in the histological appearance of the thyroid gland. He concluded that climatic conditions acting upon the thyroid are probably the most important factors in the prolongation of the larval period in *Rana temporaria*. It has been demonstrated (Fosi, 1935), however, that simply increasing the temperature is not sufficient to cause metamorphosis in tadpoles of *Rana esculenta* having neotenic tendencies. Jensen (1921) described the thyroid picture in axolotls as indicating excessive colloid storage, and a similar situation was reported for neotenic specimens of the Japanese salamander, *Hynobius* (Sasaki and Nakamura, 1937). Duchosal and Junet (1926) maintained, however, that the thyroids of neotenic *Triton alpestris* do not differ significantly in histological appearance from those of normal examples of the species. That the colloid in the glands of neotenous salamanders has an effective hormone content was demonstrated by Swingle (1922), who showed that fragments of axolotl thyroids grafted into *Rana* tadpoles induce rapid metamorphosis. In view of these facts it was suggested that the axolotl fails to metamorphose not because of any deficiency in the thyroid secretion, but because of some failure in the release of the hormone into the blood stream. Swingle (1924), however, found that removal of the thyroids from an axolotl and injection of these same glands into the peritoneal cavity did not produce metamorphosis and, in fact, injection of thyroids from two specimens was also without effect. In a few cases injection of the contents of three sets of axolotl thyroids was sufficient to induce metamorphosis. He therefore concluded that the axolotl's failure to metamorphose is due to an exceptional insensitivity of the tissues to thyroid action, an insensitivity so great that the animal's own thyroid production is insufficient to bring about metamorphic change.

Another hypothesis to account for the meta-

morphic failure, however, is that the thyrotrophic function of the pituitary is somehow impaired. It has been demonstrated that the thyroid of the young axolotl responds normally to the injection of anterior pituitary substance derived from other animals, although in older specimens the thyroid becomes inactive and no longer seems capable of response. However, Ingram (1929) has adduced evidence that in certain partially neotenic anurans there is some failure in the normal formation or release of the thyrotrophic hormone and this has been shown quite clearly in Blount's (1950) reciprocal transplants of the hypophysis between *Ambystoma tigrinum*, a readily metamorphosing form, and *A. mexicanum*, the Mexican axolotl. Mexican axolotls receiving pituitary grafts from the metamorphosing species underwent metamorphosis, while *A. tigrinum* larvae receiving axolotl pituitaries retained the larval form. Earlier experiments of this kind apparently failed because of degeneration of the transplant and, in some cases, regeneration of the host pituitary. It has already been noted that Blount and Blount (1947) have found evidence that there are two types of thyrotrophic hormone, one controlling storage and one discharge of the thyroid secretion. They have suggested that the pituitaries of neotenous amphibians elaborate the storage substance but lack the discharge hormone. Hartwig and Rotman (1940) carried on a comprehensive study of a population of neotenic *Triton taeniatus* from near Cologne. These animals all had thyroids which presented a histological picture of low activity. The authors could find nothing peculiar in the environmental features of the pond where the animals were found, and breeding experiments failed to give any indication that the neotenic condition was hereditary. Experiments indicated no loss of tissue sensitivity to thyroxin, and these authors also concluded that the neotenic condition must be ascribed to some impairment of the secretion of thyrotrophic hormone by the pituitary, even though no morphological modification of the pituitary could be detected. Extensive reviews of the early work on the axolotl are available in the papers of Schreiber (1932) and Marx (1935).

Following the successful experiments on induced metamorphosis in neotenous salamanders, great interest was aroused in attempts to induce some metamorphic change in the so-called perennibranchiate amphibians. These are forms which are not known to undergo any metamorphosis but retain their gills, tail fins, and general larval habitus throughout life. There are two well-defined families of urodeles, the Proteidae and the Sirenidae, all the members of which show this "permanent larval" condition. The Proteidae include the European "Olm," *Proteus*, and the American mudpuppy, *Necturus*. The Sirenidae are represented by the two genera *Siren* and *Pseudobranchus*, both of which inhabit the southern United States. In addition, the blind cave salamander of Texas, *Typhlomolge*, is a permanent larva usually regarded as a member of the Plethodontidae. It is natural to suppose that these forms, like the axolotl, may owe their condition to some peculiarity in the endocrine complex. Indeed, there was evidence to indicate this even before the importance of the thyroid in metamorphosis was realized, for Emerson (1905), in describing the general anatomy of *Typhlomolge*, had reported that she had failed to find any thyroid gland in this animal. Uhlenhuth (1923), in a more extensive study, found that the thyroid is actually absent in only a small percentage of specimens but is rudimentary in the others. This seems a sufficient explanation for the failure of *Typhlomolge* to metamorphose, but it is not a general explanation for all perennibranchiates. Indeed, all of the others have well-developed thyroid glands. The thyroid of *Necturus* shows typical signs of activity (Charipper, 1929), *Proteus* has a well-developed thyroid with a flattened epithelium and a predominantly chromophobe colloid (Klöse, 1931; Schreiber, 1931), and the thyroid of *Siren* is described as of normal appearance (Wilder, 1891). Swingle (1922) demonstrated that the *Necturus* thyroid contains the typical hormone, for it readily induces metamorphosis when administered to tadpoles. Grant (1930c) showed that the implantation of anterior pituitary substance is followed by characteristic colloid evacuation from the thyroid in *Necturus*, and Charipper and Corey (1930) found that the *Necturus* anterior pituitary causes precocious metamorphosis when administered to frog larvae. These same facts have been demonstrated for *Proteus* by the work of Vialli (1931). Finally Grant, Clapp, and Ruby (1932) showed that the thyroid of *Necturus* is responsive to *Necturus* pituitary; grafts of anterior lobe substance from adults into larvae caused hyperactivity of the larval thyroid and discharge of colloid.

There thus seems to be a clear indication that in most of the perennibranchiates which have been studied the endocrine complex is functional in a normal fashion. Nevertheless, attempts to produce

metamorphic changes by treatment with thyroid material or iodine compounds have been almost completely unsuccessful. Early experiments on this subject showed no effects whatsoever. As has been noted, however, Gutman (1926) reported that *Necturus* kept in a solution of thyroxin and adrenalin showed gill atrophy, protrusion of the eyes, and shedding of the skin. Noble (1924) obtained gill reduction in *Siren* and *Pseudobranchus* as a result of treatment with iodothyrin, Noble and Richards (1931) reported gill resorption and ecdysis in *Proteus* following thyroxin injection, and Noble and Farris (1929) noted some metamorphic changes in the skin of young *Cryptobranchus* raised in water containing desiccated thyroid substance. Reis (1930, 1932) has made a detailed study of the behavior of heteroplastic skin grafts in amphibians during the metamorphosis of the host. He found that grafts of axolotl skin to adult salamanders undergo a metamorphosis to skin which is of the adult type in its glandular structure and pigmentation. Extending this to the perennibranchiates, he showed that *Proteus* skin transplanted to *Triton*, *Salamandra*, or *Ambystoma* also undergoes typical transformation, even though *Proteus* skin never shows these changes in nature and cannot be induced to transform even when the animal is subjected to thyroxin treatment. Schreiber (1938) has modified the experiment by grafting *Proteus* skin to the axolotl and then inducing metamorphosis of the host by thyroxin injections. He has also shown that if axolotl skin is implanted on *Proteus* and if the *Proteus* is then given thyroxin injections, the axolotl graft will undergo metamorphosis, although the *Proteus* itself is not affected. Similar results were earlier reported by Noble and Richards (1931) for transplants of the skin of various salamander larvae to *Necturus*.

It must be concluded that the perennibranchiate amphibians retain the larval form chiefly because the tissues are extremely unresponsive to the thyroid hormone and not, except in the case of *Typhlomolge*, because of any abnormality in the endocrine complex which controls metamorphosis. Whether the perennibranchiates represent neotenic forms of which the adult stages no longer ever occur, or whether they represent forms arrested in their phylogenetic development is a question which has been interestingly discussed by Versluys (1925) and by Noble (1931), but this subject does not fall within the scope of the present review.

VI. THE THYROID AND METAMORPHOSIS IN CYCLOSTOMES AND FISHES

Cyclostomes have a larva, the ammocoetes stage, which undergoes a well-defined metamorphosis. There have been a number of attempts to demonstrate thyroid control of this process, but these have been largely unsuccessful. Feeding or injection of thyroid substance or iodine compounds does not induce precocious metamorphosis (Rémy, 1922; Horton, 1934; Stokes, 1939), and administration of extracts of the anterior lobe of the pituitary is likewise ineffective (Young and Bellerby, 1935; Knowles, 1941). It has also been demonstrated that the larval endostyle, some cells of which give rise to the adult thyroid, does not induce accelerated metamorphosis when grafted into frog tadpoles, although the gland of the adult lamprey is quite effective (Horton, 1934). Moreover, chemical analysis of the ammocoete endostyle has failed to reveal any evidence of a concentration of iodine in this region (Rémy, 1922; Horton, 1934). All of this work tends to the conclusion that, although the adult cyclostome possesses an active thyroid, the larval endostyle does not produce a thyroid hormone, and the larval tissues are not induced to metamorphose through the agency of such a hormone. Recently, however, Gorbman and Creaser (1942) have found that, after exposure of ammocoetes to radioactive iodine, a specific localization of iodine in certain of the endostylar cells can be demonstrated. The localization occurs in young larvae, less than one year old, as well as in five year old larvae ready to begin metamorphosis. In view of these findings, renewed study of the effects of thyroid administration on larval growth and differentiation in cyclostomes seems desirable.

Several bony fishes which undergo changes of a metamorphic nature during their life histories have also attracted the attention of students of thyroid physiology. Perhaps the most familiar of of these is the eel, *Anguilla vulgaris*. Murr and Sklower (1928), on the basis of a histological study of the eel thyroid, reported that the changes which occur in the gland in relation to metamorphosis precisely parallel those seen in the tadpole and therefore concluded that the thyroid is the controlling factor in causing the metamorphic changes. A much more detailed study by von Hagen (1936) revealed, however, that marked colloid release first occurs at the end of metamorphosis, at the time when the young eel passes from salt to fresh

water. Collamand and Fontaine (1942) reported that there are two periods of marked thyroid activity in the life of the eel, but these correspond to the two changes of milieu which are characteristic of the life cycle and are not related to the metamorphic process. An attempt to ascertain whether alterations in thyroid histology can be experimentally produced in marine fishes by gradual reduction of the salinity of the water was made by Olivereau (1948). He reported that this treatment results in increased epithelial height, appearance of many chromophobe vacuoles, and intense vascularization of the gland. After five or six days in water of low salinity the thyroid returns to a resting state, indicating that it is the rapid change in salinity rather than the absolute salt concentration that induces the response.

In the Atlantic salmon the transformation from the parr to the smolt stage is accompanied by active hyperplasia of the thyroid (Hoar, 1939), but since this transformation also coincides with the migration of the young salmon to the sea the significance of the thyroid change remains in doubt. Robertson (1948), however, had found a similar increase in thyroid activity in relation to the metamorphosis of the parr of the rainbow trout, a form which does not migrate to salt water, and has also demonstrated that the smolt stage can be induced by injection of mammalian thyroid extract or thyrotrophic hormone (Robertson, 1949).

Buchmann (1940) reported some evidence of a relation between thyroid activity and metamorphic changes in the herring, and Harms (1935) found that either administration of thyroxin or gradual evaporation of the water can induce accelerated metamorphosis of certain gobiiform fishes.

It is clear that the evidence for thyroid control of metamorphosis in fishes is unconvincing. Thyroidectomy has not yet been successfully performed in any of these metamorphosing forms, and conclusions drawn from histological study of the gland are controversial, particularly in view of Olivereau's demonstration of the effects of changing salinity. Administration of thyroid material to larval fishes did prove effective in Robertson's experiments, and such studies should be extended. However, the recently developed thyroid-inhibiting substances undoubtedly offer the most promising opportunity for further research on this subject.

VII. THE ROLE OF THE THYROID IN GROWTH AND DIFFERENTIATION

Despite the lack of evidence for any direct thyroid control of metamorphic changes in fishes, there are clear indications that the thyroid does play an important part in growth and differentiation in these forms. The growth rate of young brook trout is adversely affected by thyroxin administration (Herzfeld, Mayer-Umhöfer, and Scholz, 1931), and such an effect is also obtained from feeding thyroid powder to young guppies (Krockert, 1936) or immature *Platypoecilus* (Grobstein and Bellamy, 1939). Smith and Everett (1943) reported no effects on growth rate when new-born guppies are raised in water containing thyroxin or are fed with thyroid powder, but pointed out that their experiments were carried on for shorter periods than those cited above and that this might account for the result. Impairment of thyroid function by administration of thyroid-inhibiting drugs also interferes with growth in fishes (Goldsmith, Nigrelli, Gordon, Charipper, and Gordon, 1944; Frieders, 1949; Hopper, 1950). Grobstein and Bellamy (1939) found that thyroid feeding causes precocious sexual development in *Platypoecilus*, as judged by early differentiation of the gonopodium in the male, while Goldsmith, Nigrelli, et al. (1944) demonstrated that thyroid inhibition results in a failure of development of the secondary sex characters.

The available information concerning the functions of the thyroid hormone in growth and differentiation in amphibians has been considered in the section on amphibian metamorphosis.

Experimental studies on thyroid function in young reptiles are as yet entirely lacking. In adults there is conflicting evidence concerning the role of the thyroid in ecdysis. Eggert (1933) has reported that thyroidectomy causes complete inhibition of molting in the lizard *Lacerta agilis*, but Noble and Bradley (1933) found that neither thyroidectomy nor hypophysectomy prevent molting in *Hemidactylus brookii*, although the interval between molts is lengthened. Ratzersdorfer, Gordon, and Charipper (1949), working with *Anolis* treated with a thyroid-inhibiting drug, obtained still another result. In their animals the interval between molts was not affected but the duration of the molting process was greater in the experimental lizards than in controls. Finally, Schaefer (1933) has maintained that thyroidectomy has a

stimulating rather than an inhibiting influence upon molting in snakes.

In adult female horned lizards (*Phrynosoma*), thyroxin injection is reported to cause atrophy of the ovaries (Mellish and Meyer, 1937). In turtles, administration of thyroxin affects the polymorphonuclear leucocyte count in much the same way as in amphibians and in warm-blooded animals (Gordon and Charipper, 1947).

VIII. THE THYROID AND METABOLISM

The part played by the thyroid hormone in controlling the rate of metabolic activity in mammals is well known. The many attempts to demonstrate such a function in cold blood vertebrates, however, have largely met with failure (see the review of Fleischmann, 1947).

Krockert (1936) has stated that guppies fed with dried beef thyroid show an increased need for oxygen. This was simply postulated, however, on the basis of the fact that the experimental animals came to the surface oftener than the controls. In experiments in which actual measurements have been made, administration of mammalian thyroid extracts, thyroxin, or iodine compounds have been found to cause no change in oxygen consumption in the larval lamprey (Horton, 1934), or in adults of the guppy, *Lebistes* (Drexler and von Issekutz, 1935; Smith and Everett, 1943), the toadfish (Root and Etkin, 1937), the goldfish (Etkin, Root, and Mofshin, 1940; Hasler and Meyer, 1942), and *Fundulus* (Matthews and Smith, 1947). Inhibition of thyroid function in *Fundulus* by administration of thiourea also fails to affect oxygen consumption (Matthews and Smith, 1947). In view of these results, most workers have concluded that, in fishes, the thyroid hormone plays no part in the control of oxygen metabolism. Recently, however, (Smith and Matthews, 1948) it has been reported that extracts of the parrot fish thyroid are effective in inducing a significant rise in oxygen consumption when injected into another teleost, *Bathystoma*. There was considerable individual variation in responsiveness, but these results suggest that there may be some specificity in the thyroid hormone and that earlier experiments failed because of the use of mammalian extracts. In any case, the necessity for further study of the matter is indicated.

It has been noted in an earlier section of this paper that a number of workers have reported an increase in metabolic rate accompanying metamorphosis in amphibians, and some have attributed this to the increase in thyroid hormone level at this time. The most recent work on the subject, however, that of Etkin (1934), reveals no increase in oxygen consumption during normal metamorphosis in the frog. In the adult frog, thyroid administration has been reported to have no effect on oxygen consumption (Drexler and von Issekutz, 1935), but Warren (1940) found that prolonged treatment does ultimately cause a rise in oxygen consumption accompanied by a reduction in liver glycogen and a loss of body weight. Mansfeld and Lánczos (1936) and Lánczos (1939) have also maintained that administration of thyroxin or thyrotrophic hormone to adult frogs results in an increased metabolic rate, as evidenced by a rise in nitrogen excretion. Henschel and Steuber (1931), on the other hand, were unable to demonstrate any effect of thyroxin injection or thyroidectomy upon heat production in the frog. Taylor (1936, 1939) found that thyroidectomized salamanders (*Triturus torosus*) showed a decline in oxygen consumption to 72.5 per cent of the normal in two to three weeks after operation. Salamanders with two extra sets of thyroids implanted underwent an initial period of low oxygen consumption, 59 per cent of the normal rate, for about three weeks, but the rate then rose to 187 per cent of normal. The athyroid salamanders (Taylor, 1936) showed disturbances in the structure of the glands of the skin and digestive tract, and later many of the tissues exhibited signs of nutritional deficiency and emaciation. Taylor therefore suggested that the metabolic changes observed may be in part mediated by disturbances to nutrition.

Little information is available concerning the relation between metabolic rate and thyroid activity in reptiles. Drexler and von Issekutz (1935) have stated that neither thyroxin nor thyrotrophic hormone causes increased metabolism in turtles, even with long-continued treatment. Hopping (1931), however, has recorded a rise of 150 per cent in the tissue metabolism of the alligator following administration of 4.4 mg. of thyroxin.

Poikilothermous vertebrates naturally exhibit marked responses to changes in temperature, both in their general activity and in their metabolism. It has been pointed out earlier in this review that Huxley (1929), from indirect evidence, concluded that the thyroid hormone plays a part in combating the effects of low temperature in the tadpole, and the experiments of Joel, D'Angelo, and Char-

ipper (1949) demonstrate that the thyroid of the winter frog does carry on secretory activity. Nevertheless, the thyroids of most cold-blooded forms show evidences of a marked decrease in activity during the winter, and the seasonal changes in the thyroid have sometimes been regarded as the causal factors in the seasonal cycles of activity in these animals. Seasonal changes in the histology of the fish thyroid have been described by Lieber (1936), von Hagen (1936), Hoar (1939), and Buchmann (1940). Similar studies have been made on amphibians by Meisenheimer (1936), Holzapfel (1937), Pisano (1942), and Morgan and Fales (1942). There is evidence (Stein and Carpenter, 1943) that differences in illumination in summer and winter may also be a factor in the annual thyroid cycle in *Triturus*. Reptiles living in temperate regions show a seasonal change in the thyroid (Eggert, 1936; Evans and Hegre, 1940), but there is an indication, for at least one form, that the thyroid undergoes no period of marked inactivity in animals inhabiting warmer regions (Evans and Hegre, 1938).

IX. THE THYROID AND REGENERATION

The striking regenerative ability exhibited by lower vertebrates, particularly the amphibians, has made them favored objects for the study of regenerative processes. Among the many important relations brought out by early work in this field is the fact that in the Anura, and in a lesser degree in urodeles, regenerative capacity decreases during late larval and metamorphic stages and the adult has a much lower power of regeneration than does the early larva. This could be considered as a natural accompaniment of the greater degree of differentiation found in the tissues of older animals. It seems logical to suppose that the tissues of young larvae would be able to dedifferentiate and form a regeneration blastema more easily than those of older specimens, and this idea is supported by histological evidence (Goodwin, 1946).

However, the relation of regenerative ability to metamorphosis also suggests a possible influence of the thyroid hormone upon regeneration, and one might infer that a high thyroxin level in the blood has a direct inhibiting effect upon the regeneration process. Such an inference was supported by the work of Pawlowsky (1923), which indicated that regeneration of limbs is decreased both in rate and amount in thyroid-fed salamanders. Belkin (1934a), however, has maintained that the thyroid hormone has no influence upon regeneration in the axolotl, and Guyenot (1927), approaching the problem by a different method, found evidence that the loss of regenerative power is due primarily to changes within the tissues rather than to a systemic change. He transplanted limb and tail rudiments from larval anurans to salamanders in order to ascertain whether the anuran organs, which usually lose their regenerative capacity completely at metamorphosis, could be made to retain this ability to some degree throughout life, as salamanders do. Such transplanted parts lost their regenerative capacity at the usual time, however, even though the host appendages were still able to regenerate readily. Liosner (1931) carried out somewhat similar experiments, transplanting limbs from tadpoles in late metamorphic stages which had lost regenerative ability to younger specimens which were still able to regenerate. The transplanted limbs showed no recovery of regenerative power despite the changed environment. Liosner reported that in the reciprocal type of transplant, grafting limbs from readily regenerating larvae to non-regenerating specimens, no loss of regenerative capacity occurred. However, this aspect of the matter has been further investigated by Borssuk (1935) and by Poležaiev and Ginsburg (1939), and it is now clear that limbs transplanted from early to late larvae do gradually lose their ability to regenerate. Only if amputation is carried out within one or two days after transplantation is regeneration possible. It appears that there is some substance in the older animal which, given sufficient time to act, brings about changes in the younger limb that reduce its regenerative capacity (Poležaiev, 1946).

It should be noted that there are some experiments (Naville, 1927) which seem, at first sight, to cast some doubt upon this conclusion. Naville found that pieces of anuran tail can be transplanted to the dorsal lymph sacs of adult frogs and can carry on regenerative processes there for as long as several weeks. It seems possible, however, that this could be explained on the basis of a lower maintenance level of thyroxin in the adult than that which prevails in tadpoles at metamorphic climax. Studies of regeneration in metamorphosing and adult anurans under conditions of experimental hypothyroidism would be of interest in this connection.

The conclusions derived from the transplantation experiments are supported by the findings of

Speidel (1929) concerning the effects of thyroid administration upon limb and tail regeneration in the tadpole. Thyroid treatment proved effective in inhibiting regeneration, providing the hormone is given prior to, or simultaneously with, amputation. Thyroid administration after the regenerative process has begun actually causes an increase in growth rate of the regenerate and a more rapid maturing of its tissues. Similar effects were reported by Warren and Bower (1939) using di-iodotyrosine. The results of administration of pituitary extracts before or at the time of tail amputation (Herrell, 1934; Puckett, 1938) agree closely with those obtained with thyroid treatment, although in these experiments the "growth hormone" of the pituitary may be a complicating factor (Richardson, 1940, 1945). In any case, the indication is that the inhibiting influence of thyroid hormone is not one which directly affects the regenerating tissues, but is rather an effect which is exerted upon the limb or tail before amputation. Exposure to a high thyroxin level seems to induce changes in the tissues which render them less capable of regenerative activity.

Early studies of the effects of hypothyroidism upon regeneration gave conflicting results. Walter (1911) reported retardation of regeneration after thyroid removal in *Triton*, but Allen (1918) was unable to detect any such effects in *Rana*. Schotté (1926) found that hypophysectomy inhibits regeneration in adult salamanders but does not affect the process in larval *Triton*. Further investigation of this phase of the problem is needed. However, it has recently been shown (Ghidoni, 1948) that tadpoles in which a hypothyroid state has been produced by administration of thyroid-inhibiting drugs prior to tail amputation, still regenerate normally. If the treatment with thyroid-inhibitors is deferred until after tail regeneration has begun, the regenerative rate is retarded. Both of these results are in accord with the effects obtained by Speidel (1929) with thyroid treatment.

Liosner (1931), Borssuk (1935), Poležaiev (1936), and Forsyth (1946) have shown that different species of anurans differ as to the age at which the loss of regenerative power occurs, and Schotté and Harland (1943) found that regenerative ability is lost at different times at different levels in the limb, proximal levels losing the power earlier than distal levels. Moreover, it has been found that even after the period when regeneration no longer occurs under normal conditions, it may still be initiated through certain special treatments. Thus Poležaiev (1936, 1939a) succeeded in inducing regeneration of limbs in tadpoles after loss of regenerative capacity by means of traumatization, and Rose (1944, 1945) obtained regeneration in such animals by treating the wound surface with salt solution. These latter results may mean that one of the reasons for loss of regenerative ability in the frog limb at the time of metamorphosis is the change in thickness of the skin which occurs as one feature of this process. It is clear, however, that the lower regenerative power cannot be ascribed to skin changes alone, for Poležaiev (1939b) has shown that mesodermal tissues also undergo changes by which their regenerative capacities are reduced in older tadpoles.

It seems clear that there is a complex of factors involved in the loss of regenerative ability in the tadpole limb. The immediate cause of the failure of regeneration in older animals may be the high degree of tissue differentiation, the greater thickness of the skin, or some other morphological feature, but it appears that direct hormonal influences may also be involved. Both the higher level of differentiation and the altered skin structure are, of course, features which themselves depend upon the morphogenetic effects of the thyroid hormone. Grobstein (1947) has described the effects of testicular hormone upon the development and differentiation of the gonopodium of a poeciliid fish and has found that the morphogenesis of this organ is also accompanied by a loss of regenerative capacity. In his discussion of this phenomenon, he has pointed out the close parallelism between this case and that of the anuran limb, emphasizing particularly the fact that the loss of regenerative capacity in both cases is the result of morphogenetic changes produced in the organs by a hormone acting prior to the onset of regeneration. He concluded that the hormonal effects on the organs and tissues which bring about their more complete differentiation also involve local changes in tissues and cells, changes which result in reduction of their regenerative capacity. There is no doubt that this is the case. As has been seen, however, there is some evidence in the amphibians that the hormonal environment may also have a direct effect upon the regenerative process (cf. the experiments of Borssuk, 1935, and of Poležaiev and Ginsburg, 1939). This phase of the problem deserves further study.

X. THYROID ANTAGONIZERS AND INHIBITORS

A number of substances have been found to antagonize the action of the thyroid hormone or to inhibit to some degree the functioning of the thyroid gland. All of these, because of their possible use in treatment of hyperactive thyroid conditions in human beings, have been rather thoroughly tested on the common laboratory mammals. Studies of this kind on cold-blooded vertebrates are relatively few, however, and those which have been made have dealt almost exclusively with effects upon amphibian metamorphosis.

Substances reported to antagonize or neutralize the metamorphosis-inducing effects of thyroxin include: secretions of some other endocrine glands, certain chemical ions, certain amino acids, and some derivatives of tyrosine.

In early studies on endocrine factors in amphibian metamorphosis it was found that tadpoles fed on a diet of mammalian thymus gland had a delayed or completely inhibited metamorphosis, although their growth was apparently unaffected (Gudernatsch, 1912, 1914; Uhlenhuth, 1919). A considerable controversy arose concerning the interpretation of these results, some investigators concluding that the thymus produces an internal secretion with an effect antagonistic to the influence of the thyroid hormone, whereas other have maintained that thymus-fed animals fail to metamorphose because of a dietary deficiency. This matter has been discussed in a previous section of this review, and it will suffice to say here that the basis for the inhibition of metamorphosis by thymus tissue is still not clear. It is probably not to be regarded as a hormone effect. Gudernatsch (1949) now feels that some chemical component of the thymus, such as glutathione, may have an effect which antagonizes the thyrotrophic hormone of the pituitary. Hoffman (1935a) found that insulin retards the response of the tadpole to thyroxin while suprarenin accelerates it. However, these hormones presumably act through their effects on carbohydrate metabolism, rather than by a direct influence upon thyroxin activity. In this connection it may be noted that monohalogenated acetic acids, which have an antiglycolytic action, are reported to antagonize the differentiative effects of thyroxin in *Bufo* (Scarinci, 1946). Roth (1947b) has found that testosterone propionate antagonizes the effect of thyroxin upon metamorphosis in both anurans and urodeles. Larvae placed in thyroxin solutions and given simultaneous injections of testosterone propionate either fail to metamorphose or show a marked retardation of the process. The effect diminishes with increasing strength of the thyroxin solutions and, in the case of the axolotl, also varies with the age and sex of the individual. Various estrogenic hormones which were tested proved ineffective. Brandt (1936) has noted an inhibition of thyroxin-induced metamorphosis by feeding placenta or administering placental arterial blood, and Brandt and Thomas (1941) found that this inhibiting factor in the placenta is not alcohol-soluble. One might suspect that this effect is due to the chorionic gonadotrophins of the placenta, but no tests seem to have been made with purified extracts.

Several authors have attributed antagonistic effects to certain ions when administered to thyroxin-treated amphibians. Abelin (1923) reported such effects with Na_2PO_4 and concluded that phosphate ion was responsible. Zondek and Reiter (1923) maintained that calcium tends to neutralize the action of thyroxin, but Hellwig (1936), who repeated their experiments, failed to confirm their results. Sutter (1941) has found that various copper salts antagonize certain of the metamorphic effects of thyroxin, such as limb-growth, while seemingly augmenting the effects on tail resorption and loss of body weight.

Gudernatsch and Hoffman (1931, 1934) and Hoffman (1935a, b), in connection with their experiments on the effects of amino acids upon amphibian growth and differentiation, found that arginine and some other amino acids show an antagonism for the differentiation effects of thyroxin. Certain sugars and the hormone insulin were also found to retard the thyroxin effect, and methyl cyanide (acetonitrile) was reported to protect the amphibian larva against thyroxin completely. These results are regarded as supporting the view that thyroxin is to be considered as an oxidative catalyst.

Woolley (1946) has reported upon several ethers of n-acetyliodotyrosine which oppose the metamorphosing effect of thyroxin. The most effective of these were the p-nitrophenylethyl ether and the p-nitrobenzyl ether. Roth (1948) found that 3-5, D-L iiodotyrosine prevents thyroxin-induced metamorphosis if it is injected simultaneously with the beginning of thyroxin treatment or any time up to two weeks after the beginning of treatment. Injection some days before thyroxin is administered is not effective. Another material for which

thyroid-antagonizing effects have been claimed is anti-thyroidin (Belkin, 1934b), a preparation derived from the blood serum of thyroidectomized sheep; but the evidence for the effectiveness of this substance is still inadequate.

Within recent years attention has centered chiefly upon antithyroid agents which produce their effect by inhibiting the activity of the thyroid gland rather than by antagonizing or neutralizing the effects of the thyroid hormone. One type of treatment which inhibits thyroid activity has been referred to in a previous section of this review. Administration of thyroxin or iodine to an animal has the effect of depressing the animal's own thyroid. This has been well established for mammals, and iodine administration has proved useful as a preoperative treatment in hyperactive thyroid cases. In cold-blooded forms the same phenomenon has been evidenced in the work of Mayerowna (1922), Etkin (1935a), Brink (1936), and Aleschin (1936). Whether this effect of thyroid hormone and iodine upon the activity of the thyroid gland is to be explained solely on the basis of a lowering of the output of thyrotrophic hormone by the pituitary or whether some direct effect of these substances upon the thyroid gland itself is also involved is still open to question. The matter has been studied in higher vertebrates by various biochemical techniques, and the results have been critically reviewed by Astwood (1949).

There is, however, a large group of substances which apparently do have a direct effect upon thyroid function. The most active of these are compounds having a thiocarbonamide grouping, such as thiourea; but similar effects are also obtained with various amino-benzene compounds like the sulfonamides. Extensive work on mammals has not yet fully elucidated the precise mode of action of these antithyroid agents, but all of them apparently interfere in some way with the production or release of normal thyroid secretion. It is probable that some of the compounds act primarily by inhibiting the uptake of iodine by the thyroid, whereas others interfere with some phase of the enzymatic synthesis of thyroid hormone. Evidence on these points will be found in the recent reviews of Charipper and Gordon (1947), Trotter (1949), Astwood (1949), and McGinty (1949). Whatever the exact mechanism involved, the reduced output of thyroid hormone caused by administration of the antithyroid agents soon acts as a stimulus which causes increased production of thyrotrophic hormone by the pituitary. The high level of thyrotrophic hormone then brings about a hypertrophy of the thyroid gland, accompanied by hyperemia and collapse of the thyroid follicles. This thyroid hypertrophy, although it is really a secondary effect, is one of the most striking results of the administration of antithyroid drugs, and these drugs are therefore commonly referred to as goitrogens. The work on mammals indicates that in most cases the effects of the goitrogens are readily reversible, discontinuance of treatment being quickly followed by reduction of the gland to its normal size and resumption of its normal function.

The earliest report of the use of these substances in cold-blooded forms is that of Gordon, Goldsmith, and Charipper (1943). It was found that *Rana pipiens* larvae placed in a .033 per cent solution of thiourea at the hind-limb bud stage showed a retardation of metamorphosis. The effect was reversible upon cessation of treatment and could be counteracted by simultaneous treatment with thyroxin (1 part in 5 million). Hughes and Astwood (1944) demonstrated the inhibiting effect of thiouracil upon the metamorphosis of *Rana clamitans* and showed that simultaneous injection of thyrotrophic hormone did not neutralize the effect. This result indicates that in amphibians, as in mammals, the direct effect of the drug is upon the thyroid rather than through the intermediation of the pituitary. Thiourea and thiouracil have also been shown to inhibit metamorphosis in *Rana sylvatica* (Lynn and DeMarie, 1946), *Rana temporaria* (Koch, 1948), *Xenopus laevis* (Gasche, 1946; Gasche and Druey, 1946; Harms, 1949), and *Discoglossus pictus* (Bruce and Parkes, 1947; Delsol, 1948). Thiourea and phenylthiourea also cause the retention of larval features in the non-aquatic embryos of the urodele *Plethodon cinereus* (Lynn, 1947) and the anuran *Eleutherodactylus ricordii* (Lynn, 1948).

Various other thiourea derivatives and sulfonamides which have been found effective in inhibiting amphibian metamorphosis are: thioacetamide, n-allylthiourea, n-benzylthiourea (Gasche and Druey, 1946), aminothiazol (Roth, 1947a), methylthiouracil (Blakstad, 1949), and sulfanilamide (Thomas, 1947). The effects of these drugs upon the histology of the thyroid in amphibian larvae are quite similar to those produced in mammals. Gordon, Goldsmith, and Charipper (1945) recorded hypertrophy, hyperemia, heightened epithelium, and decreased colloid volume in the thyroids of

tadpoles treated for 2 to 6 weeks. Treatment over a period of 4 months resulted, however, in a regression in thyroid size and activity. Gasche (1946) reported that the follicular epithelium of the thyroid shows changes within 24 hours after the beginning of thiourea administration in *Xenopus* larvae and that chromophobe colloid is entirely lost from the follicles in 8 to 10 days. He also noted changes in the basophil cells of the pituitary similar to those which follow thyroidectomy. Administration of thiourea and thiouracil to hypophysectomized animals did not result in hyperplasia of the thyroid, a further evidence that the goitrogenic effect is attributable to increased thyrotrophic output by the pituitary. The effects of methylthiouracil upon the thyroids of *Rana temporaria* larvae (Blakstad, 1949) and of phenylthiourea upon the glands of *Eleutherodactylus* embryos (Lynn, 1948) agree with those cited above.

Recently Joel, D'Angelo, and Charipper (1949) have made a detailed study of the effects of thiourea administration upon thyroid histology in the adult frog during the winter. The gland is normally in a state of low secretory activity at this time, with colloid storage predominant and with little evidence of hormone release. Thiourea treatment was found, however, to produce marked hypertrophic and hyperplastic changes. One must therefore conclude that some hormone release does occur in the winter thyroid and that interference with this activity results in increased production of thyrotrophic hormone by the pituitary. These authors have pointed out, however, that amphibian thyroids respond less markedly to goitrogens than do those of higher vertebrates, the changes in the glands being less marked both qualitatively and quantitatively than those which occur in the chick or mammal, following approximately equivalent treatment. In the adult frog, as in the larva, long-continued treatment eventually results in regression of the thyroid. The gland may be reactivated by administration of thyrotrophic hormone, and it is therefore suggested that the regression results from exhaustion or impairment of the thyrotrophic mechanism.

By use of radioactive iodine, Bradley (1950) has been able to show that a single injection of .5 ml. of a 10 per cent solution of thiourea in the adult frog results in an impairment of the thyroid's ability to concentrate iodine, which persists for about 72 hours. Sulfanilamide treatment gives similar though less striking results.

Adult newts (*Triturus viridescens*) kept in rather strong solutions of thiourea for up to 86 days are reported to show only slight hyperplasia (Adams, 1946b). Further study might reveal more striking results at earlier stages in the treatment, however, for it seems possible that animals treated for so long a period may be undergoing a thyroid regression like that found in the frog.

Still another treatment which has been shown to inhibit thyroid activity is the administration of thiocyanate ion. The evidence at present available indicates that in mammals thiocyanate, unlike the other antithyroid agents which have been discussed, acts mainly by preventing the uptake of iodine by the thyroid. Little is known of the effects of thiocyanate treatment in cold-blooded vertebrates. Gasche and Druey (1946) found that metamorphosis of *Xenopus* larvae can be inhibited by raising the animals in solutions of ammonium thiocyanate or potassium thiocyanate. Bradley's (1950) experiments show that the thyroids of adult frogs given a single injection of 1 ml. of a .2 per cent solution of potassium thiocyanate exhibit an almost immediate impairment of their ability to take up radioactive iodine. This effect is quite short-lived, however, and the thyroid returns to complete functional efficiency within 24 hours unless thiocyanate treatment is continued at frequent intervals.

Although, as previously noted, most of the work dealing with thyroid-inhibitors in cold-blooded forms has concerned amphibians, there is sufficient information available for fishes and reptiles to give promise that goitrogens will also serve as useful tools in elucidating problems of thyroid function in these forms. Among reptiles several species of pond turtles and one species of lizard have been subjected to thiourea treatment. The turtle thyroid (Adams and Craig, 1950) responds with the usual histological signs of hyperactivity, but appears to be much less reactive than that of the mammal. In the lizard, *Anolis carolinensis*, thyroid hyperplasia and follicular collapse are readily produced by thiourea or thiouracil administration (Adams and Craig, 1949) and Ratzersdorfer, Gordon, and Charipper (1949) have shown that the hyperplastic reaction can be inhibited by simultaneous administration of thyroxin. The latter authors also found that thiourea treatment results in an increase in the duration of molting in the lizard, although the interval between molts was not affected.

Goldsmith, Nigrelli, Gordon, Charipper, and

Gordon (1944) found that thiourea caused inhibition of growth and a failure of development of secondary sex characters in a hybrid strain of fishes involving *Platypoecilus maculatus* and *Xiphophorus hellerii*. The thyroid gland showed changes similar to those recorded for other vertebrates. Similar results were obtained with two other aquarium fishes, *Aegindens latifrons* and *Trichogaster trichopterus*, by Frieders (1949); and Sullivan (1950) found that immersion of adult swordtails for a period of 47 days in either .05 per cent or .005 per cent solutions of phenylthiourea or allylthiourea resulted in very extensive thyroid hyperplasia, the glandular tissue invading the whole lower jaw region and even the bases of the gills. This invasion of surrounding tissue is probably due to the fact that the thyroid in this form, as in most bony fishes, lacks a definite capsule. Thiouracil treatment results in decreased growth rate in young *Lebistes* and also delays the maturation of the gonopodium (Hopper, 1950). The effects of thiourea treatment in fish, as in other forms, can be neutralized by simultaneous administration of thyroid material (Nigrelli, Goldsmith, and Charipper, 1946).

It is clear that antithyroid agents are effective in cold-blooded vertebrates and offer a tool by which "chemical thyroidectomy" may be readily carried out. Much more remains to be done in ascertaining the most effective compounds and the optimal dosages to be used, as well as the precise mechanism of action of the various substances before this tool can be fully exploited. It has, however, already proved useful in studies of the role of the thyroid in the embryology of amphibians having direct development (Lynn, 1947, 1948), in investigations of the relation of the thyroid to regeneration (Ghidoni, 1948) and metabolism (Matthews and Smith, 1947), and in an attempt to elucidate the possible homology of the endostyle of the ammocoetes larva with the thyroid gland (Jones, 1947).

XI. SUMMARY

The thyroid gland originates from certain cells of the larval endostyle in cyclostomes and from the embryonic pharyngeal floor in all other vertebrates. It is commonly made up of diffusely scattered follicles in teleost fishes, but in most vertebrates it is encapsulated and may take the form of a single body (reptiles) or two more or less completely separated lobes (amphibians). Histologically, the unit of structure of the gland is the follicle, which consists of a single-layered epithelium surrounding a central lumen that contains the thyroid secretion. The height of the follicular epithelium, the staining reaction of the intrafollicular and intracellular colloid, and the degree of "vacuolization" of the cells and colloid mass furnish criteria for judging the intensity of secretory activity in the gland. Despite extensive study on amphibians, the precise mechanism of release of the thyroid secretion from the follicle into the blood stream is not yet completely understood. It seems clear, however, that the stored colloid passes through the epithelial cells rather than between them, and that the release is controlled by a thyroid-activating principle secreted by the anterior lobe of the pituitary gland.

The best-known function of the thyroid hormone in cold-blooded vertebrates is in the control of amphibian metamorphosis. This function is dramatically demonstrated by the results of thyroidectomy in tadpoles, for such animals completely fail to transform into adult frogs unless thyroid hormone is administered to them. Iodine and various iodine compounds can replace the thyroid secretion in promoting amphibian metamorphosis, but this is probably due to the fact that the typical thyroid hormone can be produced by combination of iodine with the tyrosine available in the body, even in tissues other than the thyroid itself.

The thyroid gland shows a definite sequence of histological changes correlated with the stages of normal metamorphosis, and these have been quite fully described for a number of amphibians. Detailed analysis of the various bodily changes which occur during metamorphosis and of the ways in which these are influenced by thyroidectomy or thyroid administration reveals that, while most of these features are directly dependent upon thyroid stimulus, others, like the perforation of the operculum, are indirectly influenced by the thyroid, sometimes through a quite complex chain of interrelationships. The sequence and spacing of the metamorphic changes have been satisfactorily elucidated by the admirable studies of Etkin. He has demonstrated that the normal sequence of events is inherent in the tissues, while the spacing is brought about by a gradually increasing level of thyroid hormone in the blood, the rate of response in the tissues depending directly upon the hormone concentration.

Many of the events of metamorphosis involve rapid growth and differentiation, but others, such as atrophy of tail and gills, are of a degenerative

nature. Attempts to explain these diverse effects of the thyroid hormone on the basis of any single physiological action have been notably unsuccessful, and it seems quite clear that the explanation lies simply in the fact that different tissues have different and characteristic ways of responding to the thyroid stimulus. In some cases these differing modes of response have been shown to be "determined" in the tissues at quite early stages.

The secretory activity of the thyroid is controlled by a thyrotrophic hormone secreted by the anterior lobe of the pituitary. In cold-blooded vertebrates this has been most clearly demonstrated in relation to amphibian metamorphosis. It appears that, in these forms, it is the basophil cells of the anterior lobe which are responsible for thyrotrophic hormone production.

Neotenous amphibians like the axolotl offer a special problem in relation to the thyroid's role in metamorphosis. Their failure to metamorphose in nature has been variously ascribed to deficiency in the animal's thyroid secretion, exceptional tissue insensitivity to the thyroid influence, or impairment of the thyrotrophic function of the pituitary. Recent experiments, particularly those of Blount, indicate that the latter explanation is probably the correct one.

Early attempts to induce metamorphosis in perennibranchiate amphibians were unsuccessful, but the work of Reis and others on the metamorphosis of skin grafts from these forms suggests a number of other procedures which should be undertaken. Heteroplastic transplantation of gills, eyes, and other organs between young perennibranchiates and the larvae of other salamanders would be of interest. It is possible, also, that transplantation at early embryonic stages might throw further light on the origin of tissue insensitivity in these animals.

Whether the thyroid plays any part in the metamorphosis of cyclostomes or of those fishes in which a metamorphic process occurs, is doubtful. More experiments like those of Robertson, in which thyroid extract was administered to larval fishes, are needed. Moreover, in view of the possibility of some specificity in the thyroid hormone, such experiments would be more decisive if extracts of fish thyroid rather than mammalian thyroid could be used.

The most familiar effect of thyroid administration in mammals is an increased metabolic rate, as evidenced by a rise in oxygen consumption, but studies dealing with the effects of thyroidectomy or thyroid administration upon oxygen metabolism in cold-blooded vertebrates have, in general, given negative results. However, the investigations of Smith and Matthews on fishes and of Taylor on amphibians indicate that here too a species-specificity of the thyroid may be important. Experiments testing the effects of administration to cold-blooded forms of thyroid material from the same or closely related species must be carried out before any definite conclusions concerning the role of the thyroid in metabolism in these animals can be justified.

The possible influence of the thyroid secretion upon regenerative ability is another problem which requires clarification. The present indication is that the loss of regenerative capacity which occurs at metamorphosis in amphibians is to be regarded as an accompaniment of the morphogenetic changes produced in the tissues under the influence of the thyroid hormone, rather than a direct effect of the hormone upon regenerative processes. There are certain experiments, however, which seem to show that some direct influence may play a part and further study of this matter, particularly under conditions of thyroid inhibition, should be carried out.

In the study of thyroid function, as in other fields of physiology, the reptiles remain the most neglected group. This is a particularly significant gap in our knowledge in view of the intermediate position of the reptiles in the vertebrate scale as being the only poikilothermous amniotes and the group from which both birds and mammals stem. One of the chief factors hampering the study of thyroid function in both reptiles and fishes has been the difficulty in performing thyroidectomy in these animals. In fishes this is due to the usually diffuse nature of the gland. In reptiles the relatively low survival rate after operation has discouraged experimentation. The recent development of thyroid-inhibiting drugs by means of which effective "chemical thyroidectomy" can be carried out opens new opportunities for research in this field. A good beginning has already been made on such studies, and the rapid expansion of our knowledge of thyroid function in cold-blooded forms may be expected from the further extension of these investigations. Another recently developed technique, the use of radioactive iodine, has yielded important information concerning the synthesis and release of the thyroid hormone in mammals, and it promises to be equally productive in similar studies in lower vertebrates.

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ISOLATION, CULTIVATION, AND CONSERVATION OF SIMPLE SLIME MOLDS

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INTRODUCTION

THE soil-inhabiting slime molds belonging to the family Dictyosteliaceae constitute ideal material for certain types of observation and experimentation. First, they are especially suitable for studying the feeding habits of small amoeboid cells, or *myxamoebae*, since they can be grown in two-membered culture with a great variety of selected bacterial hosts (Raper, 1937; Raper and Smith, 1939). Myxamoebae free of any bacteria can also be obtained by careful selection of the spore source, should an investigator wish to study the nutritional requirements of these amoeboids in the absence of bacteria (Raper, 1937). Second, they are exceptionally favorable for investigating the organization and integration of separate but interdependent cells (Harper, 1926 et seq.; Raper, 1935 et seq.; Bonner, 1944 et seq.). Cell communities arise through the aggregation of large numbers of previously independent, free-living myxamoebae; and through the sustained cooperation of these cellular elements societal organizations, or *pseudoplasmodia*, are maintained which behave as unit structures, show marked polarity, and exhibit unitary responses to external stimuli by some mechanism suggesting hormonal control (Raper, 1940a, 1941a; Bonner, 1944, 1947, 1949, 1950; Bonner et al., 1950). Finally, they are unparalleled for observing the progressive specialization and orderly differentiation of multiple cells in the building of unit fructifications, or *sorocarps*, as the cells of "presumptive areas" in the pseudoplasmodia assume definitive positions and forms (Raper, 1940a, 1941a; Bonner, 1944, 1949, 1950; Raper & Fennell, in press). A mature fructification of specific pattern is constructed by a community of individual cells where the only force making possible such development is the intercellular organization which pervades the mass of myxamoebae prior to and during the period of cell differentiation. The life-cycle of *Dictyostelium discoideum*, a representative member of the family, is illustrated in Fig. 1.

In these slime molds, the phenomena of growth and form development represent separate and successive stages to a degree unknown in any other group of organisms. Throughout the vegetative phase the myxamoebae are free-living, independent, and unoriented, and are completely devoid of organization among themselves. Intercellular organization, on the other hand, is the very essence of the fruiting phase. Progressive stages in development are initiated and completed without the establishment of protoplasmic bridges or intercellular connections of any kind except surface contact. Since all growth ceases at the time the myxamoebae enter pseudoplasmodial organizations, problems relating to growth and to morphogenesis can be studied *per se* (Raper, 1939, 1940a, 1941a; Runyon, 1942; Bonner and coworkers, 1944, 1945, 1947, 1949, 1950; Gregg, 1950; Hirshberg and Rusch, 1950; Raper & Fennell, in press).

Appreciating the advantages which these organisms afford, investigators have given increased attention to them during recent years. However, they have not been utilized as extensively as their peculiar adaptiveness warrants. It is believed that they would be more frequently isolated, and hence more widely studied, if their abundance in nature were more generally appreciated, and if biologists realized how easily they can be isolated, cultivated, and maintained in the laboratory. Certain techniques which have been used successfully to attain these objectives will be considered in the present paper.

NATURAL OCCURRENCE AND ISOLATION

The Dictyosteliaceae are generally considered to represent coprophilous organisms, since such material represented the source of cultures studied by Brefeld (1869, 1884), Nadson (1889), Olive (1901, 1902), Potts (1902), Pinoy (1903), and others. In 1927 the Krzemieniewskis pointed out that *Dictyostelium mucoroides* Brefeld, the first

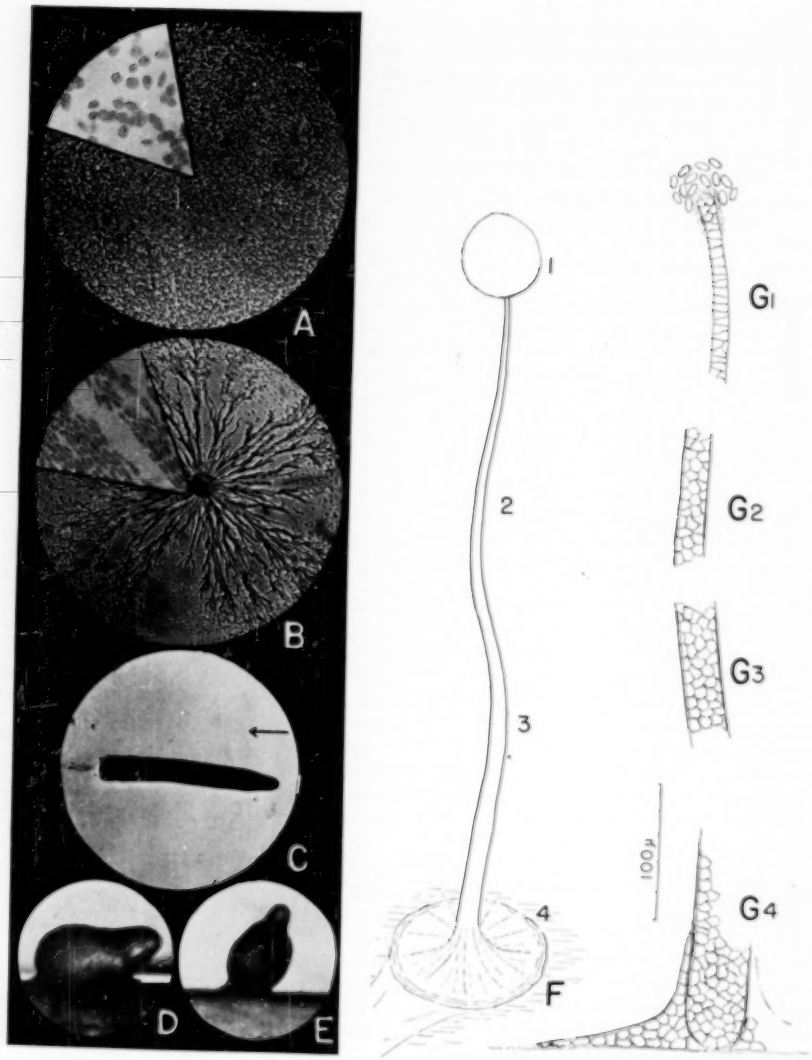


FIG. 1. DEVELOPMENTAL STAGES IN THE LIFE CYCLE OF DICTYOSTELIUM DISCOIDEUM

A, Vegetative stage, with sector enlarged to show free-living, unoriented myxamoebae. B, Developing pseudoplasmodium, with sector enlarged to show myxamoebae oriented toward the aggregation center as these converge by the coordinated amoeboid movements of individual cells. C, Migrating pseudoplasmodium moving in the direction of light (arrow). D, Pseudoplasmodium at cessation of migration and just prior to the assumption of a vertical orientation. E, Early stage in sorocarp formation. F, Diagrammatic representation of completed sorocarp showing the expanded basal disk, the upright tapering stalk, or sorophore, and the terminal spore mass, or sorus. G, 1–4, Camera lucida drawings of segments corresponding to regions indicated in F, showing the parenchyma-like nature of the supportive tissue. In the absence of any membrane surrounding the sorus the mass of spores have floated free, leaving the stalk terminus bare. Scale variable.

described and the most common species of the group, could be regularly obtained from cultivated soils in Poland, whereas *Polysphondylium violaceum* Brefeld and *Polysphondylium pallidum* Olive could be isolated somewhat less frequently from forest soils. Taking his cue from the Krzemieniewskis, Harper (1929) isolated *Polysphondylium violaceum* from garden soil collected in the parks of New York City. Subsequently, Raper and Thom (1932) demonstrated that *Dictyostelium mucoroides* could be isolated with remarkable frequency from cultivated soils of markedly different characteristics collected from widely separated areas. *Dictyostelium purpureum* Olive was isolated less frequently, and *Polysphondylium violaceum* was obtained from several samples of forest soil. More recently, Singh (1947b) has reported *D. mucoroides* to be abundant in cultivated soils in England.

For nearly two decades the writer has continued to search for these and related organisms and has substantially improved the techniques employed for their isolation. Using these improved methods, representatives of the group have been isolated in increasing numbers from a wide variety of situations, including, in addition to cultivated and forest soils, compost, dungs of various animals, decomposing grass, decaying mushrooms, rotting vegetables, musty hay, rotting wood, and blades of grass floating in stagnant ponds. One can expect to find these organisms in almost any situation where vegetable matter is undergoing aerobic decomposition.

Of all habitats investigated, samples of soil collected from the forest floor have proved most productive. In many cases, from two to four different species have been isolated from individual samples consisting of relatively little leaf mould or forest soil. In a single case, five different species were obtained from a sample of less than five grams of leaf mould (Table 1, sample 11). This is indicative of the abundance of these forms in nature and, in addition, demonstrates the ability of different species to grow in close proximity to each other and still retain their specific and distinguishing characteristics (see Raper and Thom, 1941). Five species of *Dictyostelium* and two of *Polysphondylium* are currently recognized among the strains which the writer has under laboratory cultivation. Careful comparative study of all isolates made during the past few years will probably lead to the recognition of one or more additional species. Mature sorocarps, spores, and developing pseudoplasmodia of the species discussed in the present paper are illustrated in Figs. 2, 3, and 4, respectively.

In early investigations, Raper and Thom (1932) successfully employed Ashby's mannite agar (Fred and Waksman, 1928, p. 20), a "nitrogen-free" medium containing mannite as a carbon source, to isolate species of the Dictyosteliaceae. The samples of soil, leaf mould, or other material were thoroughly ground in a sterile mortar with approximately an equal volume of sterile water, and the resulting suspension was streaked upon agar plates. The plates thus prepared were incubated for two to three weeks at 16°–18° C. to permit the slime molds to grow, aggregate, and develop mature fruiting structures. It was suggested that the chief virtue of the mannite agar might reside in its ability to support only limited growth of the fungi and bacteria invariably present in such samples. This has been subsequently confirmed, and a variety of nutrient-poor media have been successfully employed. Of such media, a dilute hay-infusion agar has been found most satisfactory. This is prepared by diluting to ¼ strength hay-infusion agar of the type previously described by the writer in studies on the bacterial host range of *Dictyostelium discoideum* (Raper, 1937). The most important consideration at this stage is to avoid the use of even moderately concentrated media. Otherwise, such slime molds as are present may be masked by a heavy overgrowth of fungi, if indeed they are not completely inhibited by an excessive production by the bacteria of metabolic products toxic to the myxamoebae. In place of weak hay-infusion agar, very dilute potato-, carrot-, or soil-infusion agars may be employed, and even peptone agar may be used if the nutrient is sufficiently dilute to preclude an appreciable rise in pH.

Based upon the writer's experience, one of two isolation procedures is recommended:

The first method is the more direct and involves the placing of small amounts of the material to be tested (soil, leaf fragments, dung, etc.) upon the surface of a non-nutrient agar plate and permitting such slime molds as are present to develop fructifications directly upon or adjacent to the material. Incubation should be at 20° to 24° C. Once fruiting structures have developed, spores are removed from sorocarps believed to be freest of contaminating organisms, and are planted in streak colonies of a selected and previously established bacterial associate growing upon some nutrient-poor agar medium. For this purpose, the writer has found *Escherichia coli* to be especially

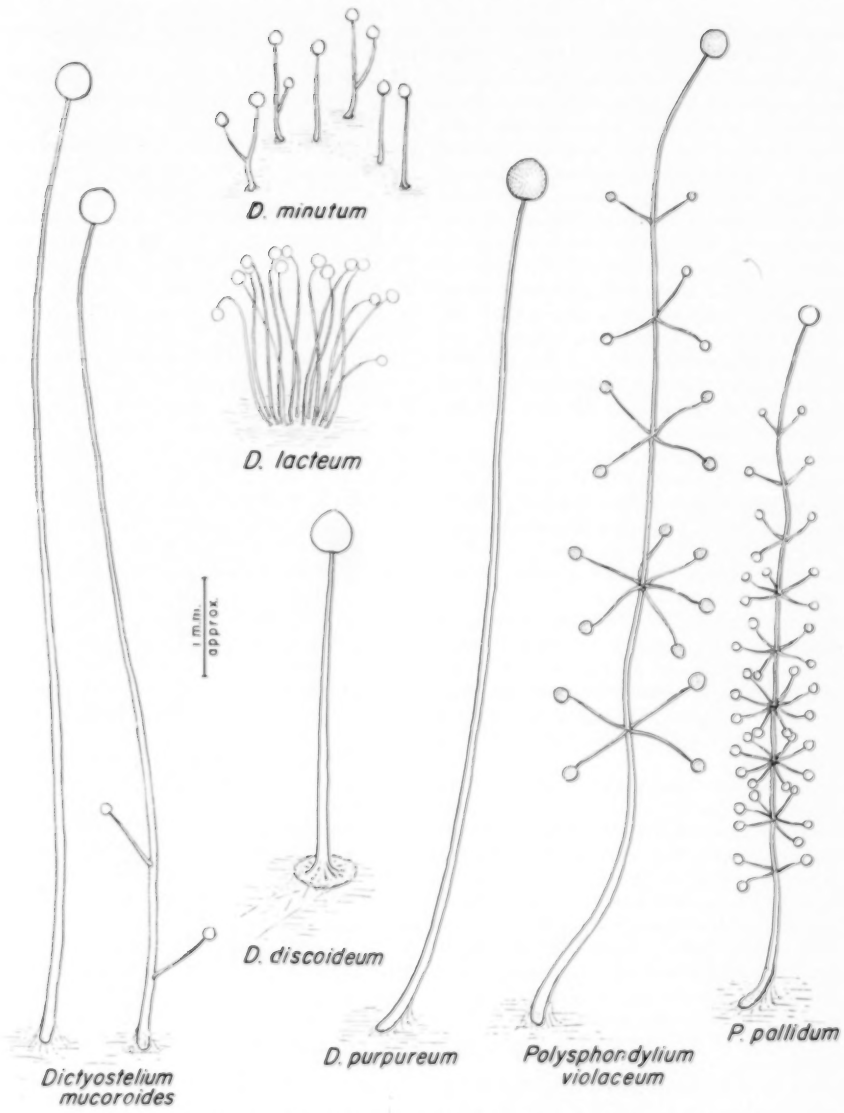


FIG. 2. SEMI-DIAGRAMMATIC FIGURES OF THE DICTYOSTELIACEAE RECOGNIZED IN THIS STUDY

Dictyostelium mucoroides, characterized by milk-white sori and long flexuous sorophores, commonly bearing small lateral branches; *D. purpureum*, characterized by deep purple sori and unbranched sorophores; *D. discoideum*, characterized by basal disks and erect, tapering sorophores; *D. lacteum*, characterized by clustered sorocarps with thin flexuous sorophores, milk-white sori, and globose spores; *D. minutum*, characterized by diminutive sorocarps, and sorophores, branched or unbranched; *Polysphondylium violaceum*, characterized by violet sori and rangy habit; *P. pallidum*, characterized by white sori and more compact habit.

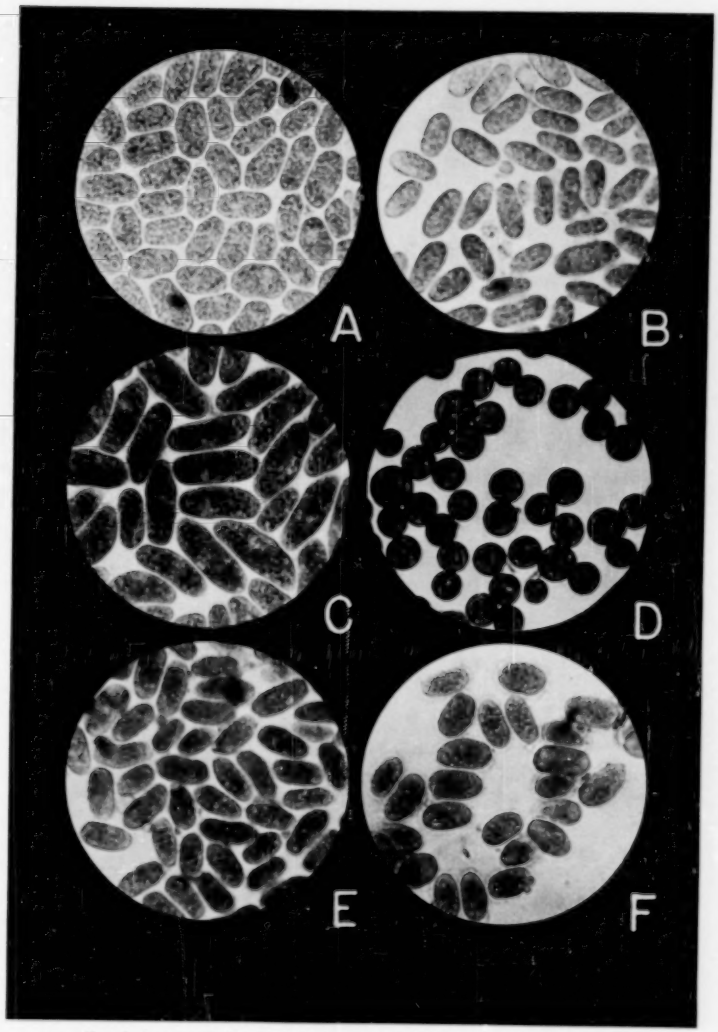


FIG. 3. SPORES OF SPECIES OF DICTYOSTELIUM AND POLYSPHONDYLIUM

A, *Dictyostelium mucoroides;* B, *D. purpureum;* C, *D. discoideum;* D, *D. lacteum;* E, *Polysphondylium violaceum;* F, *P. pallidum*. Stained with rose bengal; × 1400. Spores of *D. minutum* are not shown but closely resemble those of *D. mucoroides*.

suitable, but other species may be used satisfactorily if due consideration is given to the composition of the substrate and to the fermentative capacities of the associated bacteria (Raper, 1939). To obtain the slime mold in pure-mixed, or two-membered, culture with the chosen bacterial associate in a minimum of time, the bacterial colonies may be established as crossed streaks extending the width of the Petri dish. The spores of the slime mold are planted at the intersection of the

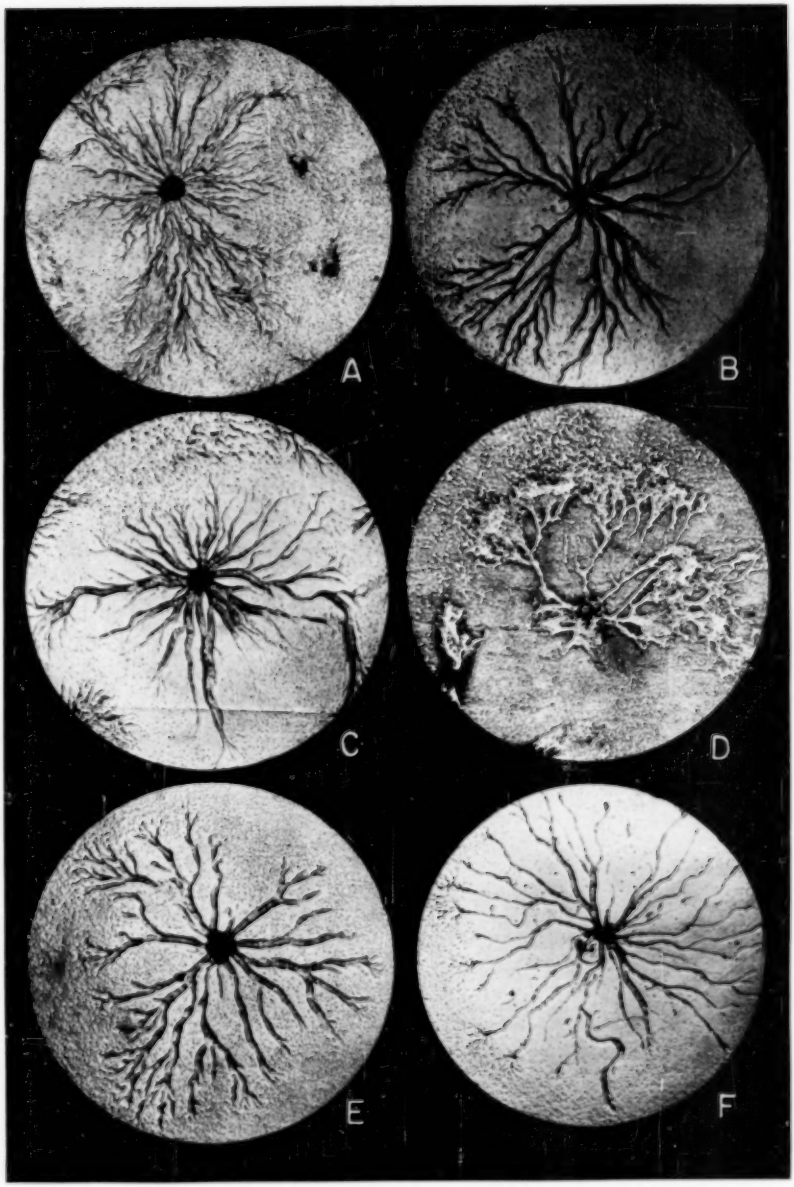


FIG. 4. DEVELOPING PSEUDOPLASMODIA OF SPECIES OF THE DICTYOSTELIACEAE

A, *Dictyostelium mucoroides;* B, *D. purpureum;* C, *D. discoideum;* D, *D. minutum;* E, *Polysphondylium violaceum;* F, *P. pallidum.* Fig. D, × 55; other figures × 16. Pseudoplasmodium of *D. lacteum* not shown but closely resembles that of *D. minutum.*

two streaks, thus enabling it to grow outward in four directions simultaneously (Fig. 5, C). As soon as the slime mold has grown to the end of either arm, or earlier if desired, a relatively small quantity of vegetative myxamoebae or spores is removed and replanted in fresh cultures of the selected bacterial associate on similar nutrient-poor agar. In this case, inoculation may be either at the end of parallel streaks or at the intersection of crossed ones. Following a second period of growth, myxamoebae or spores should again be removed and planted in new bacterial colonies. This number of transfers is usually sufficient to insure a pure-mixed culture of the slime mold with the selected bacterial associate (Fig. 5, E–F). However, in some cases, the process may need to be repeated further. This is particularly true if the slime mold, when first transplanted, is growing upon some rapidly spreading species of bacteria. It is hardly necessary to say that the cleaner the spore head is at the time of transplantation, the less difficulty will be encountered in placing the slime mold in pure-mixed culture with a selected and desirable bacterial associate.

The second method of isolation is less direct, and hence less rapid, but in the writer's experience it generally yields a greater percentage of positive results. Small samples of soil, leaf mould, or other material are thoroughly mixed with an appropriate amount of sterile water, and the resulting suspension is streaked upon ¼ strength hay agar (Fig. 5, A). Plates thus inoculated are incubated at 20°–24° C. Beginning on the third day, the plates are examined periodically for the appearance of the wheel-like aggregating pseudoplasmodia which are characteristic of the members of this group during the initial stages of fructification (Fig. 5, B). As these structures are spotted, one of two alternative procedures may be followed. The fungi, which almost invariably overlie the aggregating myxamoebae, may be removed as carefully as possible, and a small quantity of myxamoeba be transplanted directly to the intersection of crossed streaks of a desired bacterial associate growing upon a suitable nutrient-poor medium. Or, the position of a pseudoplasmodium in the original streak plate may be marked, and transplantations delayed until the fruiting structure is mature Spores would then be removed from the elevated sorus, or spore mass, and transplanted to previously established bacterial colonies. In either case further purification would be carried out as in the first method of isolation (Fig. 5, D–F). Oftentimes, a combination of the two procedures has much to recommend it.

In making isolations direct from dung, leaf mould, or soil, one has to depend upon recognition of the completed fruiting structures. Such structures are easily overlooked when intermixed with rapidly growing fungi, particularly members of the Mucorales. On the other hand, when making isolations from streak plates after only a few days' incubation, one looks for a structure (the aggregating pseudoplasmodium) which is at once distinctive and unique to this group. There is, in addition, the further fact that the myxamoebae in a tested sample may not be able to develop mature fructifications because of localized unfavorable conditions, whereas these same myxamoebae may proliferate if streaked upon agar plates where they are subjected to more favorable conditions.

A few examples will be cited to illustrate the abundance of the Dictyosteliaceae in nature, and the effectiveness of the above procedures for isolating these slime molds in pure-mixed culture with *Escherichia coli*.

In October 1937, a series of leaf mould samples was collected from a deciduous forest near Vienna, Va. The general site of the collections was an area, bordering a small stream, where the principal vegetation consisted of oaks, maples, ash, beech, alder, and ferns. The samples were taken from an intermediate layer, i.e., they contained no surface (undecayed) leaves and little underlying disintegrated humus material. Small portions of the samples were ground with 5 to 10 volumes (weight) of sterile water in a clean mortar (washed and burned out with alcohol) and were streaked on weak hay-infusion agar plates. Incubation was at 20°–21° C. Results are shown in Table 1.

In June 1950, a series of soil and leaf mould samples was collected in "Westwood," Purdue University, Lafayette, Indiana. Samples consisted of nearly decomposed leaf material, humus, and top soil to a depth of one inch, and were collected at various locations within a 4 to 5 acre tract of dense deciduous forest growth. The predominant trees were oaks, maples, beech, and hickory, with a fairly heavy undergrowth of shrubs and herbaceous plants. Some of the samples were taken from low land bordering a small stream, whereas others were collected on gentle slopes that rise from it. In the laboratory, small portions of the samples were thoroughly shaken in test tubes with 8 to 10

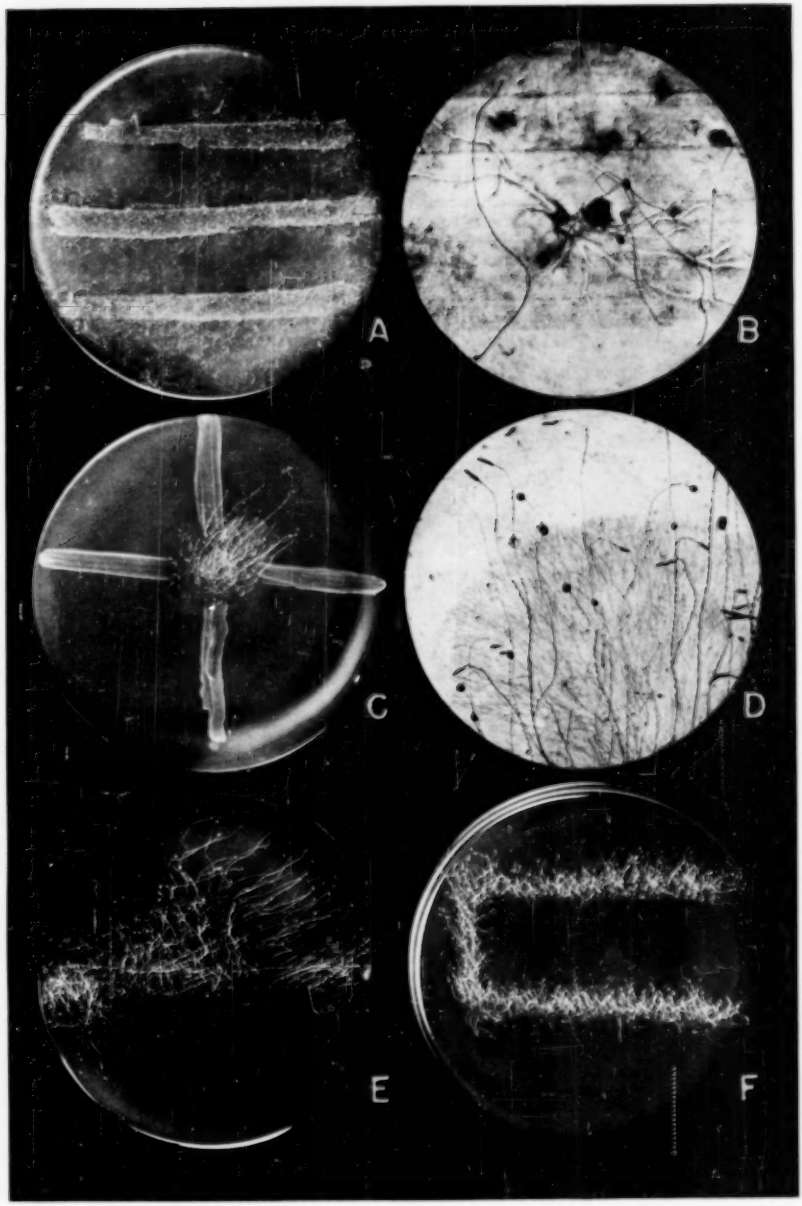


FIG. 5

volumes of sterile water, allowed to stand for 2 to 3 hours, then reshaken prior to being streaked on weak hay-infusion agar plates. Incubation was at 24° C. A record of the slime molds isolated from these samples is presented in Table 2.

In May 1950, a series of soil and leaf mould samples was collected from "Brownfield Woods," Urbana, Illinois. In the main, these samples consisted of well decayed leaf fragments, humus, and surface soil. Brownfield Woods represents a virginal wooded tract which is maintained as a natural area by the University of Illinois. The predominant trees are oaks, maple, ash, hickory, and hackberry, with considerable undergrowth of smaller trees and shrubs. The samples were collected on the gentle slopes that rise from a small stream which flows through the tract. In the laboratory, the samples were handled in the same manner as the preceding. Results are summarized in Table 3.

A second series of samples was collected from Brownfield Woods in October 1950. Since the exact sites of the spring collections were not marked, it was impossible to obtain precise duplication of source material. An effort was made, nevertheless, to collect samples from the same general areas with a view to comparing the relative abundance and identity of slime molds present at the beginning and near the close of a growing season. The second series of samples was handled in a manner identical with the first. The number of slime molds isolated from the October series was approximately equal to that obtained in May, and no species were encountered in the second series which had not been seen in the earlier one.

In addition to the slime molds which were isolated, all samples showed a variety of soil amoebae ranging in size from ca. 75–100 μ down to 6–8 μ, including terricolous types, various encysted species, and forms which became flagellate when transferred to water or liquid nutrient media. Several of the soil amoebae were isolated in two-membered culture with *E. coli*, but none were identified as to species. Although the techniques described here have not been employed for the specific purpose of isolating soil amoebae, they should prove applicable for this purpose if one wished to undertake a comparative study of this very abundant and inadequately studied group of microorganisms.

TABLE 1

Slime molds isolated from soil and leaf mould samples collected from a deciduous forest near Vienna, Virginia, October 1937

SPECIES ISOLATED	SAMPLE NUMBER												
	1[1]	3	5	6	7	8	9	10	11	12	13	14	15
Dictyostelium mucoroides Brefeld	+	+		+		+		+	+	+	+	+	
Dictyostelium purpureum Olive	+						+		+				+
Dictyostelium discoideum Raper									+	+	+		
Dictyostelium minutum Raper		+											
Polysphondylium violaceum Brefeld		+		+		+	+		+	+			+
Polysphondylium pallidum Olive	+	+				+		+	+	+	+		+
Myxomycete plasmodia[2]	+	+		+			+		+	+			

[1] Sample No. 2 represented an unidentified pyrenomycete, whereas sample No. 4 consisted of wood fragments from a well decayed oak log; *D. mucoroides* was isolated from the former, no slime mold from the latter.

[2] Myxomycete plasmodia were isolated and grown in laboratory culture for a brief period but were not identified.

FIG. 5. ISOLATION OF THE DICTYOSTELIACEAE FROM SOIL

A, Soil suspension streaked on dilute hay-infusion agar, 5 days. B, Enlarged view of developing pseudoplasmodium (*Dictyostelium mucoroides* in this case) from *A*, × 10. C, Myxamoebae from *B* planted at the intersection of crossed streaks of *Escherichia coli*, 3 days. D, Enlarged view of portion of colony similar to C; note development of sorocarps beyond margin of underlying fungus growth, × 5. E, Spores (or myxamoebae) from longest sorocarps in D inoculated at left end of *E. coli* streak, 6 days. (The slime mold in growing through the *coli* streak frees itself of the bacterial species initially associated with it.) F, Spores (or myxamoebae) from a selected sorocarp at the right end of streak in E removed and inoculated with a pure culture of *E. coli* upon a fresh plate of hay-infusion agar, yielding a pure-mixed, or two-membered, culture of *Dictyostelium mucoroides* and *Escherichia coli*. (See further discussion in text).

PRINCIPLES OF CULTIVATION

The Dictyosteliaceae occur naturally in organic residues which are undergoing aerobic decomposition, and it is apparent that they survive and grow in nature by feeding upon the variety of bacteria present in such habitats. The writer (Raper, 1937) failed to find any evidence of symbiosis or intimate relationship between particular species of slime molds and the bacteria with which they were originally associated, although this had been claimed by earlier investigators (Nadson, 1899; Pinoy, 1903; Skupienski, 1918), who isolated *D. mucoroides* with *Bacillus fluorescens* (*Pseudomonas fluorescens* of current usage). *Dictyostelium discoideum* was found to be capable of growing in association with a wide variety of saprophytic (Raper, 1937) and parasitic bacteria (Raper and Smith, 1939). There is no reason for supposing that other slime molds cannot do likewise if suitable culture conditions are established.

TABLE 2

Slime molds isolated from soil and leaf mould samples collected from a deciduous forest (Westwood) at Purdue University, June 1950

SPECIES ISOLATED	SAMPLE NUMBER															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
D. mucoroides			+[2]	+	+					+	+	+	+	+	+	
D. purpureum											+		+			
D. minutum	+	+				+[3]		+[3]	+[3]	+		+	+	+		+
D. lacteum v. Tieg.		+			+		+									
Dictyostelium sp.[1]				+	+											
P. violaceum						+		+								
P. pallidum														+		

[1] Believed to represent a new species, being characterized by yellowish and much branched (irregularly) sorophores and milk white sori.

[2] Possibly represents *D. brevicaule* Olive, being characterized by white citriform sori and short heavy sorophores.

[3] *D. minutum* apparently, but differing from typical strains since it produces abundant "macrocysts" on dilute peptone-dextrose medium.

TABLE 3

Slime molds isolated from soil and leaf mould samples collected from a deciduous forest (Brownfield Woods) at Urbana, Illinois, May 1950

SPECIES ISOLATED	SAMPLE NUMBER											
	1	2	3	4	5	6	7	8	9	10	11	12
D. mucoroides				+	+	+		+[2]				
D. purpureum						+						
D. minutum										+	+	
D. lacteum					+	+						
Dictyostelium sp.[1]	+		+									+
P. violaceum	+	+		+		+		+		+	+	+
P. pallidum	+				+							

[1] Duplicates the probable new species isolated from samples collected in Westwood, Purdue University; see Table 2.

[2] A strain producing very long and comparatively coarse sorophores, probably identical with Singh's *Dictyostelium giganteum*, see p. 188.

To maintain a culture of *Dictyostelium* or *Polysphondylium* in association with a selected bacterial species, it is necessary only to transplant to suitable substrata mass inocula of slime mold spores, or myxamoebae, together with some of the associated bacteria. Normally, if a few mature sorocarps are transferred by means of a small loop, bacteria will be present in sufficient quan-

tities to furnish adequate inoculation, even in cultures where these seemingly have been completely consumed. As reported earlier, isolated sorocarps of *Dictyostelium discoideum* are bacteria-free, and so constitute an exception to this generalization (Raper, 1937). The same is true of the sori, or spore masses, of other large species such as *Dictyostelium mucoroides* and *Dictyostelium purpureum* when these are produced on long stalks and are well removed from their sites of origin. In any of these species, however, sorocarps taken from within the area of the original bacterial colony, will carry with them sufficient bacteria to initiate the new colony. With some bacterial hosts there is a marked tendency to develop rough or slimy variants which, if perpetuated, constitute a less favorable food supply for the slime mold. For this reason it has become routine practice to prepare and use fresh bacterial suspensions from stock cultures each time a slime mold is retransferred. Spores of *Dictyostelium* or *Polysphondylium* for such recultivations are regularly taken from well isolated sori, or in the case of very delicate species, such as *Dictyostelium minutum* or *D. lacteum*, from the cleanest possible area of the old colony. The reader is referred to the several papers by the writer dealing with the growth and development of these forms, particularly *Dictyostelium discoideum* (Raper, 1935, 1937, 1939, 1940a).

Choice of Bacterial Associates

In cultivating slime molds belonging to the Dictyosteliaceae, the choice of a bacterial associate should be governed in large measure by the nature of the investigation. If the principal objective is a study of the vegetative phase, with particular reference to the feeding habits of the myxamoebae, the slime mold can be cultivated most advantageously with *Bacillus megatherium* because of the large dimensions of its cells (Raper, 1937). If a more general study is intended, or if the primary objective is to follow the fruiting process particularly in its earlier stages, cultivation in association with some smaller-celled, non-spore-forming species is more satisfactory. This is true particularly because the spores of *Bacillus megatherium* are not digested and commonly accumulate in sufficient quantities to obscure the normal movements of the myxamoebae during the period of orientation and the early stages of aggregation which characterize pseudoplasmodium formation.

Of the many bacteria employed by the writer (Raper, 1937, 1939) as hosts for *Dictyostelium discoideum* and other species of simple slime molds, *Escherichia coli* was found most suitable. Two properties recommend this species particularly: (1) on the majority of media it normally produces moist, non-gummy colony of a physical character especially favorable for the feeding of the slime mold myxamoebae; and (2) it characteristically produces neither acid nor alkaline byproducts in excessive quantities if available nitrogen and carbon sources in the medium are properly balanced. There are, of course, the further advantages that it is easily identified, is cosmopolitan in distribution, and is immediately available to all investigators.

For special experiments such as the grafting of pseudoplasmodial fractions (Raper, 1940a), or the mixing of different species of slime molds (Raper and Thom, 1941), the strongly pigmented species *Serratia marcescens* affords exceptional advantages. In association with this species, the myxamoebae and pseudoplasmodia of *Dictyostelium discoideum*, *D. purpureum*, and *Polysphondylium violaceum* become colored by the undigested pigment, prodigiosin, which remains within vacuoles in the bodies of the myxamoebae. In contrast, the cells of *D. mucoroides*, *D. minutum*, and *Polysphondylium pallidum* digest this pigment, and hence remain colorless.

Pseudomonas fluorescens, the bacterial species present in Nadson's (1899), Pinoy's (1903, 1907), and Skupienski's (1918, 1920) cultures provides excellent nutriment for the myxamoebae of these slime molds, but special precautions must be exercised to prevent the culture medium from becoming excessively alkaline as a result of their intense proteolytic activity (see p. 181).

A shift from pure-mixed culture with one host bacterial species to another can be accomplished by the same general techniques originally employed for the isolation of these slime molds from natural sources. Spores from selected sorocarps developed with one host species are transferred directly to previously established streak cultures of the second host, this procedure being repeated one or more times as necessary. In the case of *D. discoideum*, this will be realized regularly in the first transfer if spores are taken from isolated sorocarps that have developed from migrating pseudoplasmodia and are situated 1 cm. or more beyond the limits of bacterial growth (Raper, 1937). In other large species, such as *D. mucoroides*, *D. purpureum*, and *P. violaceum*, the same result may be attained on the first trial if spores are

taken from soil borne on sorophores a few centimeters in length and are, as a result, well removed from the sites of sorocarp origin.

The conventional methods developed for the cultivation and study of *Dictyostelium* and *Polysphondylium* are based upon the growth of the host bacterium on a selected agar medium, coupled with the simultaneous or delayed introduction of the slime mold which feeds upon the bacteria in situ.

If one wishes to investigate pseudoplasmodium development, i.e., the aggregation of myxamoebae, two drops of a suspension of slime mold spores and host bacteria may be spread evenly in a broad band (1–2") upon the surface of a nutrient-poor agar plate (see p. 181), a bent glass rod being used to effect this distribution. Under these conditions the bacteria and the slime mold make an even but comparatively thin growth, and pseudoplasmodia will begin to develop throughout the area within 42 to 46 hours when incubated at 22°–24° C. Such a culture is illustrated in Fig. 6, A. If one wishes to observe the development of a succession of pseudoplasmodia, bacteria alone may be spread in the manner described, and spores of the slime mold may be subsequently added at the center of the plate. In this case, pseudoplasmodia will first appear within approximately two days and will continue to develop for several days as the slime mold progresses toward the plate margin.

When quantitative measurements of growth are contemplated, it is preferable to plant the bacterial associate two or three days prior to the introduction of the slime mold, and plates should be used in which the surface is sufficiently dry to prevent the bacteria from spreading beyond the intended area of the colonies thus established.

When large migrating pseudoplasmodia of *Dictyostelium discoideum* (or developing sorocarps of other species) are desired (Fig. 8), richer substrata should be employed. Bacteria and slime mold may be inoculated simultaneously, or the introduction of the latter may be delayed until the bacteria have made a substantial growth under conditions which will preclude the development of an unfavorable pH (Raper, 1939) or the production of toxic metabolites. In any case, the area of inoculation should be limited so that broad, bacteria-free expanses remain wherein the pseudoplasmodia may migrate and the sorocarps develop.

Singh (1946, 1947a), at the Rothamsted Experiment Station in England, has described an alternative procedure that is very useful and has special applications. *Aerobacter* sp. (strain 1912) or some other soil bacterium is first cultivated on nutrient agar (2–7 days), then one or more loopsful of the bacterial paste are transferred to the surface of a non-nutrient agar plate containing 0.5 per cent NaCl, establishing a "bacterial circle" into which the spores of the slime mold are introduced. This technique enables one to consider more nearly independently those factors affecting slime mold growth which result from the substratum and those which are directly attributable to the bacterial cells. A method similar to this was occasionally used (but not reported) by the writer (Raper, 1940a) to secure maximum red pigmentation of migrating pseudoplasmodia for grafting experiments with *D. discoideum*. Singh (1947b) used it most effectively for isolating species of *Dictyostelium* from soil and compost and for maintaining these in continued laboratory culture.

By adding fresh bacterial suspension to a culture of *D. discoideum* at appropriate intervals, the onset of aggregation can be appreciably delayed; and by transferring vegetative myxamoebae to fresh colonies of bacteria at intervals of 36 hours or less, cultures can be continued indefinitely in a vegetative state quite devoid of fruiting phenomena (Raper, 1940b). Single myxamoebae when transplanted to favorable bacterial colonies reproduce the entire life cycle to yield wholly normal cultures of *Dictyostelium*—such cultures being marked only by a considerable delay in the appearance of the first pseudoplasmodia and sorocarps.

Whereas the myxamoebae of *Dictyostelium* normally feed upon living bacteria, they can be grown successfully upon dead bacterial cells. In 1937 the writer reported the successful cultivation and normal development of *D. discoideum* on cells of *Serratia marcescens* killed by exposure to flowing steam and on cells of *Achromobacter radiobacter* killed by exposure to ultraviolet light. In neither case was an attempt made to carry the slime mold through a second culture generation.

Recently, in discussion with the writer, Drs. C. P. Haskins and S. H. Hutner emphasized the need for such information, and a more comprehensive series of experiments was undertaken. *Escherichia coli* was grown in four liquid media, as follows: (1) Lactose 1 per cent-peptone 1 per cent; (2) dextrose 1 per cent-peptone 1 per cent; (3 and 4) the same but containing M/100 $Na_2HPO_4 \cdot 12\ H_2O$ and M/100 KH_2PO_4. Incubation was at 28° C. for 60

hours with vigorous shaking. The bacterial cells from one liter of whole culture were concentrated by centrifugation, washed in 0.5 per cent saline, recentrifuged, suspended in 20 ml. saline, and sterilized at 121° C. for 20 minutes. The final pH of the cell suspensions from the unbuffered media was 5.8 or 5.9, from the buffered media 5.5 in each case. Using micropipettes, ¼ inch wide streaks were made on freshly poured plates of lactose-peptone agar (1.2 per cent each ingredient) and inoculated immediately with bacteria-free suspensions of *D. discoideum* spores, the purity of the suspensions being verified in tubes of nutrient broth incubated at 30° C. Parallel cultures with live *E. coli* were made, using similar lactose-peptone agar plates. Growth of the slime mold with killed bacteria was somewhat less rapid, with migrating pseudoplasmodia appearing in 4 days rather than 3 as in the control cultures with living *E. coli*. Consumption of the streaks of killed bacteria, however, was complete within 5 or 6 days, and the development of the slime mold was entirely normal throughout. Migrating pseudoplasmodia were typical in form and size and not infrequently migrated for 6 to 7 cm. prior to the formation of typical sorocarps.

This type of recultivation has now been repeated for seven successive weeks, in each instance the spores having been taken from sorocarps produced in the preceding series of cultures grown on killed bacteria. During these seven culture generations there has developed no evidence that the slime mold is becoming less vigorous in its growth or less characteristic in the pattern of its completed sorocarps. There would seem to be no reason for suspecting that this slime mold might not be grown indefinitely upon killed bacteria. By careful analyses of such bacterial suspensions perhaps we may be able, in time, to compound synthetic media capable of supporting luxuriant growth of these slime molds in the complete absence of bacterial cells, either living or dead.

Essential Characteristics of Culture Media

Just as the bacterial associate should be chosen with special regard to the nature of the study, so should the culture medium be varied with reference to the same factor. In addition, it should be compounded with reference to the normal fermentations of the bacterial associate. These are generally not critical if nutrient-poor media that are reasonably well buffered are utilized, since neither an excess of acidity nor alkalinity is ordinarily built up. They may be critical, however, if inadequately buffered media containing nutrients such as peptone are employed. They will almost certainly be critical with nutrient-rich media unless special measures are taken to prevent the reaction from becoming either excessively acid or alkaline. This may be accomplished in many cases by properly balancing the carbon and nitrogen sources, and failing in this it can be attained generally by adequately buffering the medium with phosphate buffers (Raper, 1939). The favorable pH range for the group as a whole appears to be between pH 4.5 and 8.0, and for the species *Dictyostelium discoideum* between pH 5.0 and 7.0, with an optimum about 6.0–6.2.

If the objective is to demonstrate some characteristic development such as the aggregation of myxamoebae in pseudoplasmodium formation (Fig. 6, A), a medium of relatively low nutrient content is desirable. If on the other hand, the objective is to obtain a particularly rich culture of the slime mold or to secure abundant pseudoplasmodia of large dimensions for observation and experimentation, then a medium of greater nutrient content is indicated (Fig. 6, B).

Based upon the writer's experience, a number of solid media (1.5 or 2.0 per cent agar) have been found especially valuable in cultivating *Dictyostelium discoideum* and related species in association with *Escherichia coli*. Of this number the following four are particularly suitable for observing and studying the vegetative growth of myxamoebae and the process of pseudoplasmodium formation:

(1) Hay-infusion agar as earlier described (Raper, 1937, p. 293).
(2) Hay-infusion agar with 0.05 per cent added peptone.
(3) Peptone-lactose, or peptone-dextrose agar containing 0.05 or 0.1 per cent of each ingredient.
(4) Carrot-infusion agar prepared by boiling 300 g. of fresh carrots per liter of water, reconstituting the filtrate, and adding sufficient agar to make a firm jell.

The last medium is somewhat richer than the three preceding, but not sufficiently so to make pH adjustment necessary. This medium is normally mildly acid in reaction, which renders it all the more favorable for the Dictyosteliaceae. Of the four media listed, the first and second are

quite satisfactory for cultivating *Dictyostelium discoideum* in association with *Serratia marcescens*, and the first three are satisfactory for cultivating this slime mold in association with *Bacillus megatherium*. Only the first can be considered entirely satisfactory if *Pseudomonas fluorescens* is used as a bacterial associate.

More luxuriant growth and development of *Dictyostelium discoideum* may be obtained by cultivating it in association with *Escherichia coli* upon solid media (1.5 or 2.0 per cent agar) of greater nutrient content. Of many such media studied, a few of those frequently employed are listed herewith:

(5) Peptone yeast extract dextrose agar, wherein peptone and yeast extract are used in 0.2 per cent concentration and dextrose 0.5 per cent.

(6) Peptone-lactose agars, wherein both nutrients are employed in a concentration of 1.0 or 1.2 per cent.

(7) Peptone-dextrose agars of like nutrient concentration.

(8) Enriched hay-infusion agar, wherein 0.5 per cent peptone is added and the medium is buffered with M/50 concentrations of KH_2PO_4 (2.7 g./l.) and $Na_2HPO_4 \cdot 12\ H_2O$ (7.16 g./l.).

(9) Enriched carrot-infusion agar, wherein peptone and phosphate buffers are added as in the preceding.

(10) Potato-infusion agar (infusion prepared by boiling 400 g. fresh potato per liter of distilled water), wherein peptone and phosphate buffers are added as above.

(11) Canned pea broth agar, wherein the broth from canned green peas is used in 10 per cent concentration and is enriched with 0.5 per cent peptone and M/50 phosphate buffers.

(12) Bonner's agar: Peptone, 10 g.; dextrose, 10 g.; $Na_2HPO_4 \cdot 12\ H_2O$, 0.96 g.; KH_2PO_4, 1.45 g.; agar, 20 g.; distilled H_2O, 1000 ml. This medium is compounded with a view to insuring an initial pH of about 6.0 (Bonner, 1947).

(13) Prepared agar media: Eosin-Methylene Blue Agar or Endo Agar (Difco) constitute favorable substrata. These are especially good when used at half nutrient strength

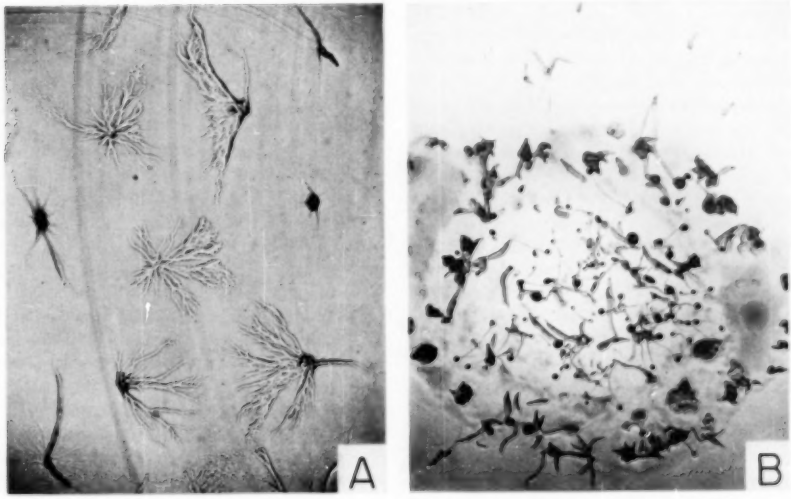


FIG. 6. COMPARISON OF PSEUDOPLASMODIUM FORMATION IN THIN AND RICH CULTURES OF DICTYOSTELIUM DISCOIDEUM IN ASSOCIATION WITH ESCHERICHIA COLI

A, Two-day culture on hay-infusion agar showing characteristic radiate pattern of developing pseudoplasmodia in thin culture, × 6. B, 3½-day culture on 1.2 per cent lactose-1.2 per cent peptone agar showing the characteristic manner in which pseudoplasmodia develop in rich culture, × 4.

with sufficient additional agar to yield a firm gel. Cultures should be incubated at a low enough temperature to prevent the development of a metallic sheen on *E. coli* colonies.

Of the above agar media, Nos. 8 and 9 normally support good growth of *Dictyostelium discoideum* in association with *Serratia marcescens*. None of the above are especially suitable for *Pseudomonas fluorescens* or *Bacillus megatherium*, although No. 8 may be regarded as reasonably satisfactory for the latter. In the presence of dextrose or lactose, *Bacillus megatherium* produces a large gummy colony that is physically unsuitable for feeding by myxamoebae, quite aside from any consideration of pH (Raper, 1939).

Medium No. 12 has been used extensively for growing luxuriant crops of myxamoebae of *D. discoideum* for demonstrating the production and role of "acrasin" (Bonner, 1947, 1949, 1950), for studying respiration (Gregg, 1950), and for investigating the effects of various compounds on the process of cell aggregation (Hirschberg and Rusch, 1950).

Dictyostelium mucoroides, *D. purpureum*, and *Polysphondylium violaceum* can be cultivated satisfactorily in association with *Escherichia coli* upon any of the media listed above, and, generally speaking, the amount of growth for any of these species will be roughly proportional to that of *D. discoideum* under like circumstances. The more delicate species, *D. lacteum*, *D. minutum*, and *P. pallidum*, can be cultivated satisfactorily only upon the nutrient-poor agars, and they make their most characteristic development on media Nos. 1, 2, and 3. The reasons underlying this behavior are not thoroughly understood and deserve careful investigation.

In the case of *Dictyostelium discoideum*, the suitability of existing culture conditions can be accurately gauged by the behavior and response of the slime mold itself. From the writer's experience, six degrees of response may be cited, ranging from complete absence of growth to optimal growth and development as follows:

(1) The spores fail to germinate.

(2) Limited growth of myxamoebae occurs, but no cell aggregates (early pseudoplasmodial stage) are formed (Fig. 7, A).

(3) Fair growth of myxamoebae occurs, and a few, generally atypical pseudoplasmodia form but seldom migrate.

(4) Good growth of myxamoebae occurs, typical aggregates develop, and some pseudoplasmodia migrate; but sorocarps are generally very atypical (Fig. 7, B).

(5) Good growth of myxamoebae occurs, typical aggregates are formed, and extensive migration usually follows; but sorocarps are generally atypical with short and unevenly tapered stalks, ill-formed basal disks, and very irregular sori.

(6) Good growth of myxamoebae occurs, aggregation is wholly typical, migration is extensive, and mature sorocarps are characterized by erect and evenly tapered stalks, broad flattened basal disks, and citriform to nearly globose sori (Fig. 7, C).

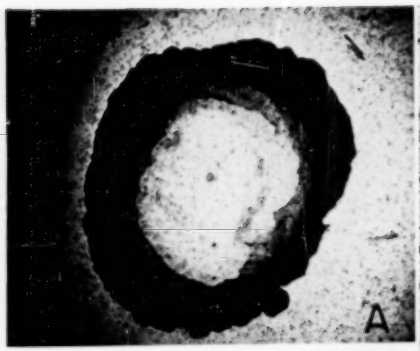
It has been reported previously (Raper, 1939) that these general levels of behavior can be correlated with ranges in pH, varying from completely unfavorable (pH 8.5–8.6) to optimal (pH 6.0–6.2). A similar but less precise degree of correlation can be made between behavior and (1) incubation temperatures and (2) relative humidities within the culture vessels.

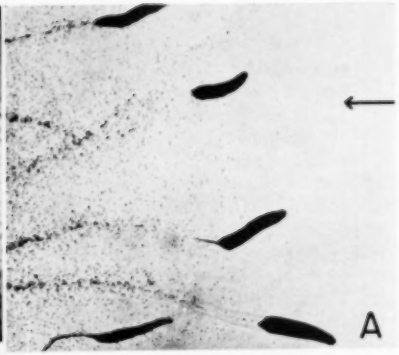
The character of the slime deposit left in the wake of the migrating pseudoplasmodium of *D. discoideum* likewise reflects to a considerable degree the suitability of a given culture. Regularly, a few myxamoebae become dislodged from the migrating body to remain in the slime deposit, where they often become more or less vacuolate. Under conditions of too high temperature, too low humidity, or too great acidity or alkalinity, the number of myxamoebae remaining in the deposit increases tremendously, thus rapidly exhausting the migrating body and lending to the so-called slime streak a conspicuous and irregular cellular texture.

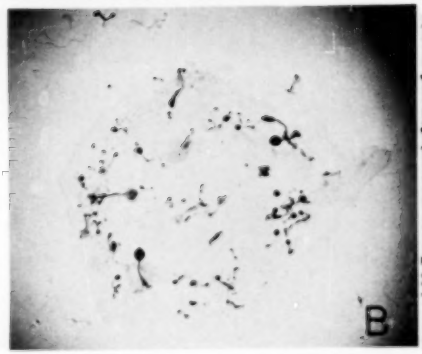
The same general relationships of slime mold to culture conditions can be observed in the other large species. However, since none of these possess a migrating stage and none develop a basal disk, the degrees of response are less striking and clean-cut, although in *Polysphondylium violaceum* the extent and regularity of branching does afford a fairly reliable index. As suggested by Singh (1947a), *Dictyostelium mucoroides* and *D. giganteum* (p. 188) appear to be less sensitive to pH than *D. discoideum*.

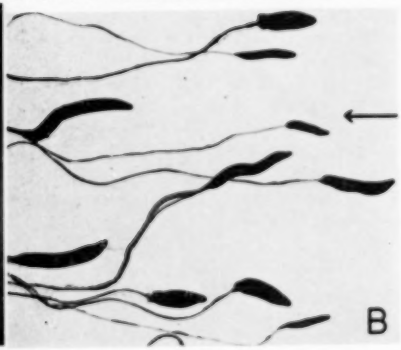
Effects of Temperature, Humidity and Light on Growth and Development

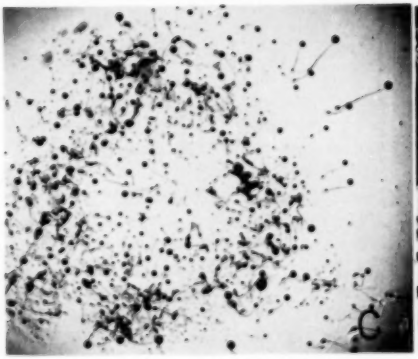
In addition to the identity of the bacterial associate and the composition of the culture











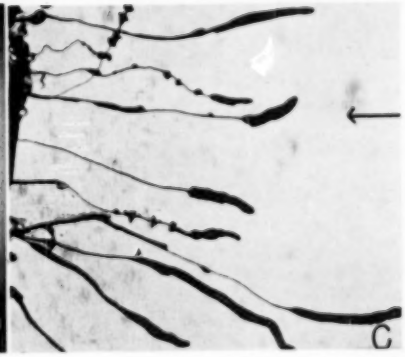


FIG. 7 FIG. 8

FIG. 7. GROWTH AND DEVELOPMENT OF DICTYOSTELIUM DISCOIDEUM IN ASSOCIATION WITH PSEUDOMONAS FLUORESCENS AND ESCHERICHIA COLI IN CULTURES OF VARYING SUITABILITY

A, Very unfavorable culture conditions; the myxamoebae made a limited growth (indicated by clearance of bacterial colony) but failed to form pseudoplasmodia. B, Unfavorable culture conditions; the bacterial colony was consumed, pseudoplasmodia were formed, but the resulting sorocarps are few in number and atypical in pattern. C, Optimal culture conditions; abundant sorocarps of typical pattern have developed. A and B, Bacterial associate; *Pseudomonas fluorescens;* C, *Escherichia coli*. 8 days. × 3.

FIG. 8. RESPONSE TO LIGHT OF DICTYOSTELIACEAE

A, Migrating pseudoplasmodia *Dictyostelium discoideum*. B, Developing sorocarps of *D. purpureum*. C, Developing sorocarps of *Polysphondylium violaceum*. Direction of illumination indicated by arrows. × 12.

medium, other factors, including temperature, humidity, and light, markedly affect the growth, development, or both, of *Dictyostelium* and *Polysphondylium*. The optimum temperature varies somewhat depending upon the species, but generally appears to range between 20° and 25° C. Cultures of all species can be grown successfully at lower temperatures, and developmental processes proceed in an entirely normal manner; however, the rate of growth and development is somewhat retarded. It has been previously demonstrated that the onset of the fruiting stage can be hastened by raising the temperature of incubation (Raper, 1940a), and that migrating pseudoplasmodia will move from the cool (15°–16° C.) toward the warm side of a Petri plate culture. Bonner and coworkers (1950) have recently demonstrated this response in cultures where the gradient is as little as 0.05° C., and by calculation they conclude that the temperature difference at the two sides of a small migrating pseudoplasmodium (0.1 mm. diam.) would be approximately 0.0005° C.—an amazingly sensitive response. Recently, Bonner and Slifkin (1949) have shown that if pseudoplasmodia or young sorocarps are exposed to an abrupt rise in temperature a marked reduction in the percentage of stalk cells results. After fruiting for repeated generations at 27° C., the normal proportions of stalk to spore cells are restored; in all cases vegetative growth occurred at 21°–24° C. in diffuse light.

Maximum growth and optimum development occur in a saturated or nearly saturated atmosphere; hence, cultures should be grown at all times in tubes with snug-fitting cotton plugs or in Petri dishes consisting of close-fitting valves. If such cultures can be incubated in a chamber with controlled humidity, an added advantage is realized.

There is at present no evidence to indicate that light either enhances or retards the rate or amount of myxamoebic growth. In many species, however, light does exert a marked influence on the fruiting process. Raper (1940a) showed that pseudoplasmodia develop from 2 to 4 hours earlier and are smaller and more numerous in cultures of *Dictyostelium discoideum* grown in diffuse daylight than in similar cultures incubated in total darkness. Potts (1902) and Harper (1931) reported that sorocarps of *D. mucoroides* and *Polysphondylium violaceum*, respectively, are larger when formed in darkness than in light. Subjected to one-sided and comparatively weak illumination, the responses for the larger species are most striking. In *D. discoideum* there is a consistent and pronounced migration of pseudoplasmodia toward light prior to sorocarp formation (Fig. 8, A). Fruiting structures produced under these circumstances are often formed at an angle of 30° or more from the vertical, whereas in darkness or in uniform light sorocarps are characteristically built perpendicular to the surface where they originate. Sorocarps of *D. mucoroides*, *D. purpureum*, and *P. violaceum* formed in one-sided illumination are regularly constructed in the direction of the light source (Fig. 8, B & C), and appear to be characterized by longer sorophores than are typical of sorocarps produced in the dark; they are unquestionably longer than those produced in evenly illuminated cultures. Current information is insufficient, however, to permit citation of quantitative relationships. Light seems to exert little or no effect upon dimensions or orientation of fruiting structures in such delicate species as *D. lacteum* and *D. minutum* (Raper, 1941b).

Incubation of large species such as *Dictyostelium discoideum*, *D. mucoroides*, *D. purpureum*, and *P. violaceum* in one-sided illumination contributes immeasurably to the ease with which they may be placed in two-membered cultures with a selected, or different, bacterial associate (see p. 179).

MAINTENANCE OF CULTURES

All species of *Dictyostelium* and *Polysphondylium* which have been isolated and studied by the writer can be maintained indefinitely in laboratory culture by periodic transfer with suitable bacterial associates to appropriate agar media. When maintained in continuous culture, such stocks should be renewed every 3 or 4 months, and in the interim between periods of actual growth and development at 20°–24° C. (5–6 days) they should be stored in a refrigerator at 3°–6° C. to reduce evaporation and to extend viability. Nutrient-poor media are recommended, and either of the four agars listed on p. 181 is satisfactory, although, in my experience, hay-infusion agar has been used most generally. In recultivations from such cultures one should bear in mind that the culture is two-membered, and failure of the slime mold to grow may result either from the death of it or of the bacteria upon which it feeds.

Agar slant cultures of slime molds and *Escherichia coli* commonly remain viable for 6 to 8

months or more, but if valuable stocks are to be maintained in this way, prudence demands that they be rechecked more frequently. In one series of tests nine strains of *Dictyostelium* and *Polysphondylium* were examined after storage in a refrigerator for one year. Five were viable, including representatives of *Dictyostelium discoideum*, *D. purpureum*, *D. mucoroides*, *Polysphondylium violaceum*, and *P. pallidum*. The viable strain of *D. mucoroides* developed slowly, indicating that few live spores remained at the time of retransfer. The four strains which did not grow represented a typical *D. mucoroides* and three isolates doubtfully separable from this species. In other cases, cultures expected to be viable have failed to grow after six months. In the test of year-old cultures, the associated bacteria remained viable in every case.

Professor John T. Bonner, Princeton University, has reported (personal communication) considerable success by covering agar slant cultures with sterile heavy mineral oil, using the method described by Buell and Weston (1947) for conserving various fungi. Cultures of *Dictyostelium mucoroides*, *D. giganteum* Singh (1947a), *D. discoideum*, *D. purpureum*, *P. pallidum*, and *P. violaceum* were uniformly viable after 10 months. One preparation of *D. discoideum* was viable after 33 months, whereas two others failed to grow after 26 and 20 months, respectively. One preparation of *D. mucoroides* remained viable after 32 months, another after 31 months, while still others were dead at 24. One preparation of *D. purpureum* grew after 2 years; another of the same age failed to grow. Cultures of *P. pallidum* and *P. violaceum* failed to grow when tested at 2 years. The viabilities of cultures covered with oil were sufficiently variable to suggest that environmental conditions (pH, metabolic products, etc.) existing therein, when the oil was applied, might have been factors determining longevity.

The lyophil process, as used for the preservation of molds (Raper and Alexander, 1945; Fennell et al., 1950) and yeasts (Wickerham and Flickinger, 1946) has proved ideal for the conservation of *Dictyostelium* and *Polysphondylium*. Attempts to preserve the myxamoebae, or vegetative cells, have been wholly unsuccessful. However, the spores, or reproductive cells, can be preserved superbly. Several lyophil preparations for each of 17 strains were prepared in May and June, 1941. Viability tests have been made periodically since that time. Table 4 summarizes the results obtained in three comparative tests, the first at 15–16

TABLE 4

Viability of lyophilized cultures of Dictyostelium and Polysphondylium in association with Escherichia coli

SPECIES	STRAIN	DATE LYO-PHILIZED	VIABILITY TESTS						CULTURAL RESPONSE IN THIRD TEST
			Test No. 1		Test No. 2		Test No. 3		
			Age in mo.	Viability	Age in mo.	Viability	Age in mo.	Viability	
D. discoideum	NC-4	6-20-41	15½	++++[1]	31	++++	105	++++	Pseudoplasmodia developing at 2 days
" "	V-12	6- 4-41	16	++++	31½	++++	105	+++	Few pseudoplasmodia at 2 days
D. minutum	V-3	5-29-41	16	++	31½	++++	106	+++	Pseudoplasmodia developing at 4 days
D. mucoroides	V-10	6-10-41			31½	++++	105	++++	Pseudoplasmodia abundant at 2 days
" "	Hall	6-19-41			31	++++	105	+++	Pseudoplasmodia developing at 4 days
" "	NC-12	5-29-41	16	++	31½	++++	106	++	" " " " "
" "	S-2	6- 4-41	16	++++			105	++++	Pseudoplasmodia developing at 2 days
" "	Thom	6-19-41	15½	++++			105	++	Growth of *Dictyostelium* apparent 2 days after new *E. coli* added[2]
D. purpureum	V-1a	5-29-41	16	++++	31½	+++	106	++++	Pseudoplasmodia developing at 2 days
" "	V-15	6-19-41	15½	++++	31	++++	105	++++	" " " " "
" "	D-6	6- 4-41	16	++++	31½	++++	105	++++	" " " " "
" "	G-4	6- 4-41	16	+++	31½	++++	105	++++	" " " " "
P. pallidum	V-1b	6-20-41	15½	++++	31	++++	105	+++	Pseudoplasmodia developing at 3 days
" "	Martin[3]	6-19-41			31	++++	105	++++	Pseudoplasmodia developing at 4 days
P. violaceum	P-6	6-19-41	15½	++++	31	++++	105	++++	Pseudoplasmodia developing at 2 days
" "	V-6	6-20-41	15½	++++	31	++++	105	++++	" " " " "
" "	V-9	5-19-41	16½	++++	32	++	106	++++	" " " " "

[1] ++++ = Excellent Viability; +++ = Good Viability; ++ = Fair Viability; and + = Poor Viability.

[2] No evidence of bacteria or slime mold growth after 4 days; fresh *E. coli* suspension added, some myxamoebae present 2 days thereafter, and pseudoplasmodia appeared at 3 days.

[3] Not a two-membered culture; original bacterial associate and *E. coli* present at time of lyophilization.

months, the second after an additional, equal interval, and the final one at 105–106 months. The second test is of some interest because it approximates the duration of Bonner's oil-seal experiments. The third is particularly significant since it covers a period of almost 9 years without evident loss of viability. In fact, the appearance of developing pseudoplasmodia (wheel-like cell aggregates) within two days from slime mold-bacteria suspensions prepared from lyophilized cultures equals, within a very few hours, the minimum time required to reach a comparable stage of development when fresh suspensions of bacteria and slime mold spores are used for inocula. In a single case (*D. mucoroides*, strain "Thom") the bacteria were no longer viable, hence no growth occurred in the first transfer; upon the introduction of live *E. coli*, growth and development of the slime mold occurred forthwith.

The ability to conserve slime molds in a desiccated state proved most valuable during the period from 1941–1949, the writer's attention then being wholly directed toward other problems and endeavors. It is probable that valuable stocks, upon which much work had already been done, would have been lost during this period had it proved necessary to transfer these cultures every few months. As successive viability tests were made, it became increasingly clear that properly prepared lyophilized cultures would undoubtedly last for years, and our anxiety regarding strain perpetuation gradually subsided. While we cannot possibly estimate the probable viability of such preparations, we can now report that cultures thus conserved for nearly a decade still show neither apparent loss of viability nor reduction in vigor.

Whereas no systematic search for slime molds was made during the period 1941–1949, many soils from different stations in this country and abroad were examined for antibiotic-producing molds. From time to time slime molds were observed, isolated, and lyophilized, and a considerable backlog of strains was built up. Recently, a more concerted effort has been made in this direction, and the results shown in Tables 2 and 3 are representative of the success attained. By continuing to lyophilize new strains as these are isolated, it is believed that sufficient material will soon be available to justify a thorough comparative study of this abundant but inadequately known group of microorganisms.

At the outset of this paper the opinion was expressed that greater study would probably be given to the Dictyosteliaceae if their abundance in nature were more generally appreciated, and if the ease with which they can be cultivated in the laboratory were better known. One can perhaps presume, also, that these simple slime molds may be more commonly discussed and exhibited in various science courses when it is realized that a dozen vials containing bacterial cells and slime mold spores can be processed once each decade. In the interim, a single tube can be opened each year 3 or 4 days before demonstration or classroom material is required.

DISCUSSION

In the study of any organism, the influence of the cultural environment upon growth and developmental processes should be thoroughly understood. In the case of the Dictyosteliaceae, or pseudoplasmodium-forming slime molds, this is especially important. The amount and rate of growth of the myxamoebae reflect directly the suitability and richness of the accompanying bacterial growth as a source of food for these slime molds. The manner in which the myxamoebae come together to form pseudoplasmodia, and the way in which these subsequently differentiate to build sorocarps reflect equally well the suitability of particular cultural environments for optimal morphogenesis. In *Dictyostelium discoideum*, for example, one can very quickly appraise the appropriateness of a given set of culture conditions (p. 183), and steps can be taken to improve this by giving careful consideration to the composition of the culture medium with reference to the fermentative capacities of the associated bacteria, attention to incubation temperature, etc. *Needless to say, basic cultural conditions should be optimal before one attempts to study additional factors affecting pseudoplasmodium formation and migration, the behavior of pseudoplasmodial fractions, or any analysis of cellular differentiation associated with sorocarp formation.*

No other species of the Dictyosteliaceae has been studied as carefully as *Dictyostelium discoideum* in laboratory cultures. Nevertheless, upon the basis of long experience, it can be stated that conditions which are optimal for the growth and development of this species are, with few exceptions, also optimal for *D. purpureum*, *Polysphondylium violaceum*, and the larger forms of *D. mucoroides* (see below).

Some of the species considered in the present paper are easily recognized and no confusion can

possibly exist regarding their identity. Others show marked variability, and it is sometimes difficult to know which strain or strains should be regarded as representative of particular species.

Dictyostelium purpureum Olive (1901) represents the only species characterized by deep purple spore heads, or sori. The species is common on dung and in forest soil.

D. discoideum Raper (1935) is the only species that produces a basal disk, and is the only one in which the pseudoplasmodia migrate prior to the initiation of sorocarp formation. This species has been isolated on two occasions only, in both cases from deciduous forest litter.

D. lacteum van Tieghem (1880) is the only species reported to have spherical spores; in addition its sorophores typically consist of a single row of cells. After remaining unreported for 70 years, it has been isolated several times recently from deciduous forest soil (see Tables 2 and 3).

Polysphondylium violaceum Brefeld (1884) is characterized by large, branched (whorled) sorocarps and sori that are pale violet in color. It is especially abundant in forest soil and leaf mould.

D. minutum Raper (1941) is distinguished by its diminutive size, with sorocarps that are generally more or less clustered and are frequently and irregularly branched. Occasional strains produce "macrocysts" which appear to represent abortive sorocarps. This species is very abundant in soils from deciduous forests.

Polysphondylium pallidum Olive (1901) is characterized by branched (whorled) sorocarps and white sori (50–80 μ). Olive (1901) described two species of *Polysphondylium* with white sori, pointing out that *P. album* was characterized by larger sori (100–300 μ) which were usually more numerous in the whorl. Polysphondylia with white sori and beautifully formed sorocarps are commonly isolated from forest soil and leaf mould. A careful comparative study of available isolates should be made, using different culture media and different bacterial associates. Only in this way can one hope to determine whether Olive worked with a single or with two distinct species. Excellent as was his work in many respects, Olive (1901, 1902) had no idea concerning the identity of the bacteria associated with his cultures, nor did he have any conception of their crucial role in the nutrition of his slime molds.

Dictyostelium mucoroides Brefeld (1869) is the oldest species in the group, the most abundant in nature, and the most variable. In fact, Dictyostelia with white sori and flexuous sorophores are so variable and so commonplace as to preclude anything approaching a precise definition of this species. Either through wisdom or neglect, Brefeld did not specify any range of dimensions for mature sorocarps of *D. mucoroides*. Potts (1902) reported sorocarps 2–2.5 mm. in length and commonly branched. Olive (1901, 1902) gave sorocarp lengths as "2–3 mm. to 1 cm. or more," and noted that spores and mature fructifications showed extreme variability in size. Pinoy (1907) reported structures 1 cm. or more in length. In my own experience scores of strains have been observed upon hay-infusion agar in association with *Escherichia coli*. Some of these isolates regularly produce short erect sorocarps and possibly represent Olive's concept of *D. brevicaule* (1901); others, cultivated in one-sided illumination, develop sorocarps up to 5 cm. or more in length and seem to duplicate Singh's new species *D. giganteum* (1947a); still others produce irregularly branched sorocarps with yellow to yellowish sorophores bearing milk white sori, hence fail to conform with any described species. The writer has believed it prudent to adopt a broad concept of *D. mucoroides*, and to regard this name as applicable to a series of variant types rather than attempt to limit its use to a few strains which generally produce sorocarps in a particular size range.

A thorough comparative study of the larger white-spored Dictyostelia and the white-spored Polysphondylia should be made using selected bacterial associates, defined culture media, and uniform illumination and temperature of incubation. Only in this way can one distinguish clearly which differences are inherent in the slime molds and which merely reflect variations in the cultural environment.

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SUMMARY

Attention is called to the abundance in nature of the Dictyosteliaceae, or pseudoplasmodium-forming slime molds, and methods are described for isolating them in two-membered culture with

selected bacterial associates. *Escherichia coli* is recommended for routine laboratory cultivation, whereas *Serratia marcescens* and *Bacillus megatherium* possess unique advantages for special investigations.

The culture medium should be compounded in the light of the fermentative capacities of the associated bacteria; the pH should be maintained within a favorable range (pH 5.5–7.0) either by the use of buffers, or as the result of a balanced breakdown of substrate ingredients. A list of recommended culture media is presented.

Cultures should be incubated within a favorable temperature range of 20°–25° C., should be grown in a saturated atmosphere, and may be exposed to one-sided illumination to secure maximum migration (*Dictyostelium discoideum*) and development of the longest possible sorophores (*D. purpureum*, *D. mucoroides*, and *Polysphondylium violaceum*).

Cultures of the Dictyosteliaceae can be conserved for periods in excess of eight years without appreciable decline in viability when slime mold spores and associated bacteria are preserved by the lyophil technique.

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PUSH-BUTTON EVOLUTION

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A review of THE BIRTH AND SPREAD OF PLANTS. *Boissiera, Volume 8.*

By J. C. Willis. Conservatoire et Jardin Botaniques, Geneva; American distributor: Chronica Botanica Co., Waltham, Mass. $6.00. (paper) viii + 561 pp. 1949.

To those who know the two earlier books of J. C. Willis: *Age and Area* (1922), and *The Course of Evolution* (1940), the present work comes as no surprise. It is merely an extension of the ideas presented in those volumes. The most important of these are as follows: Evolution has proceeded "from larger down to smaller divisions of the vegetable kingdom." In other words, the different modern families first differentiated from each other; then the genera became differentiated; and finally the species and lesser categories. Furthermore, each family originated from another family and each genus from another genus, by a single mutation which produced at one step all of the familial or generic differences. Not only that, but the larger (and therefore "older," in Willis's opinion) genera originated not from forms similar to them morphologically, but from very different types. Thus "The first mutation in Compositae from *Senecio* probably gave rise to *Hieracium*, thus beginning the two great subfamilies *Tubuli-* and *Liguli-florae*" (p. 265).

These "divergent mutations" have, according to Willis, occurred with a regular frequency, "probably largely dependent upon chemical and electrical phenomena" (p. 489). As a consequence, forms truly intermediate between the modern families and genera do not exist and have never existed in the past. The apparent transitions "are more correctly interminglings of complete characters" (p. 491). Few species have ever become extinct during the course of geological time; nearly all of the species of flowering plants which have ever been formed still exist today.

As a result of these conclusions, which are stated dogmatically as clearly demonstrated facts, adaptation and selection are stated to be of minor, almost negligible importance in evolution. All new types are produced at one step by a single mutation, and selection merely eliminates those types not adapted to their environment.

Based upon these conclusions, as well as upon the "Age and Area" hypothesis, Willis has concluded that any taxonomic system based upon morphological characteristics, including all of the systems now proposed, is certain to be highly artificial. According to him (p. 322), a natural classification of the various categories "is evidently largely dependent upon their mere age," i.e., the largest (and therefore "oldest") genera of a family should be placed next to each other regardless of their similarity or dissimilarity. He therefore concludes that "a genetic system of classification would be too complicated for practical use" (p. 505).

As all who have followed recent work on evolution are aware, Willis's ideas are diametrically opposed to those of most modern biologists who have written on this subject, such as R. A. Fisher, Julian Huxley, Th. Dobzhansky, Ernst Mayr, G. G. Simpson, Bernhard Rensch, and the present reviewer. For this reason, one should carefully examine his evidence, to see whether or not such a revolution in thinking is justified.

Such an examination reveals first the fact that Willis has not relied upon any of the conventional lines of evidence for evolution. Fossils are said to consist almost entirely of offshoots from the main line of evolution; so that the fossil evidence is summarily dismissed. The belief that there is no connection between genetic relationship and outward appearance disposes at once of all evidence from comparative morphology, anatomy, or embryology. His genetic "evidence" consists entirely of speculations upon the possible nature of the postulated "divergent mutations." Willis has performed no experiments himself,

and seems to be completely ignorant of the literature of genetics, both as regards the fundamental principles themselves, or their application to evolutionary problems. In his literature list the vast modern literature on the genetics of species and of interspecific hybrids is represented by only 2 short papers of a general nature, one by S. C. Harland and one by the present reviewer. The experimental work on the nature of species carried out by such botanists as Turesson, Müntzing, Clausen, Keck, and Hiesey, Winge, Edgar Anderson, Turrill, and Gregor is completely ignored.

Actually, therefore, the only evidence presented by Willis in support of his ideas is that from geographic distribution, and from the relative sizes of different genera belonging to a family. This "evidence," as in previous work of Willis, is compiled from various monographs and floras. It is based upon two generalizations which Willis considers to be axiomatic: first that the ages of the different species of a genus are roughly proportional to the areas which they occupy, the older species having the wider ranges; and second, that the sizes of genera are proportional to their ages, the largest being the oldest. If these generalizations are strictly true, then Willis's conclusions follow automatically; since, as he shows by means of detailed surveys of regional floras of Britain and several parts of Europe, and of the families Acanthaceae, Monimiaceae, and Araceae, the two most widespread genera of any family are very different from each other morphologically, as are also the largest genera of any family.

Willis's two axioms, in turn, are supported by indirect evidence, which he nevertheless considers to be incontrovertible. This is the "hollow curve," which is a graphical expression of the fact that in any genus there are a few widespread species, many more with intermediate ranges, and by far the largest number have a narrow range. Similarly, in any family or tribe, one or two genera are very large, several are of intermediate size, and the largest number have only one or two species. This "hollow curve" type of distribution occurs so regularly that it cannot be entirely the result of chance, but must have some cause. In my opinion, Willis is correct on this point. But Willis believes that the only possible explanation is the one worked out by him and the statistician, G. Udny Yule, namely, that all of the species of a genus arise in the same region at regular intervals and migrate outward at approximately equal rates. Furthermore, the parental species survive; there is little extinction.

The fallacies in Willis's reasoning have been pointed out so many times by the reviewers of his two earlier books (See *Q. R. B.*, 16: 209. 1941), that they do not need to be discussed in detail here. However, a few of the most glaring inconsistencies may be mentioned. In the first place, although he states (p. 389) that a large family is large because it is old, and suggests "that the whole step from one class to another might be taken by one operation" (p. 479), he is nevertheless reluctant to push his logic to its ultimate conclusion, namely, that the oldest family of seed plants (and, in fact, of the entire plant kingdom) is the largest, the Compositae. This is obviously a reductio ad absurdum, but there is nothing in either Willis's "evidence" or logic that prevents one from reaching such a conclusion. Second, through his ignorance of genetics, Willis accepts Fleeming Jenkin's criticism (1867) of the Darwinian theory, namely, that a slight improvement in adaptation will be lost by crossing with an unimproved form. The recognition of genes as permanent hereditary units has, of course, long ago invalidated this argument. Third, he consistently treats genera and species in his lists as single units, although in many places he argues that many of them are polyphyletic. Finally, his insistence that there has been very little extinction of species or genera is entirely at variance with the fossil record, which shows that nearly all of the forms existing in the Cretaceous or early Tertiary periods are either extinct or else do not grow any longer in the regions where their fossils are found.

Willis's summary dismissal of adaptation as a factor in the origin of species is, of course, entirely at variance with the experimental results of all modern geneticists who have worked on the species problem. His point of view seems to spring from the naive concept that the only differences between two species or genera are those which are used in the keys to their identification. If we admit the conclusion which is based upon the numerous experiments of Turesson, Clausen, Keck, and Hiesey, and many others, namely, that the differences which adapt species to different habitats are in general entirely different from those by which they are most easily identified, then much of Willis's argumentation falls to the ground. Natural selection is now known to be a very complex series of phenomena; and the fact that the particular adaptation of a particular species, or the selective value of a particular character, cannot be detected by the casual human observer, does not mean that it is non-existent. Man's observational powers are not so omniscient.

The two points on which Willis insists most strongly are first, that in respect to many of the most important differences between families or genera an intermediate condition is impossible, and second, that the only explanation of the "hollow curve" type of distribution is Age and Area. In both of these points he is, in my opinion, mistaken. With respect to the first, if one considers the plant as a whole, there is probably no single character difference in which intermediate conditions cannot occur. For example, Willis states that leaves must be either opposite or alternate; no intermediate condition is possible. This is true if one considers only a single node; but many plants exist in which some of the nodes have the opposite and others

the alternate type of leaf arrangement, as in the common sunflower (*Helianthus annuus*.) Such a condition would be the probable one in a hybrid between one species having only opposite and another having only alternate leaves. I have myself had experience with a comparable example. In the grass genus *Agropyron* the spikelets are solitary at each node of the inflorescence, while in many species of the related genus *Elymus* each node bears two spikelets. No intermediate condition is possible; half spikelets cannot exist. But the F_1 hybrid between *Agropyron parishii* and *Elymus glaucus* is intermediate between its parents in respect to that character; most of the spikes in this hybrid bear two spikelets on some of their nodes and one spikelet on others. Furthermore, in *Agropyron smithii*, which in many respects varies in the direction of *Elymus*, differences exist between clones in respect to the percentage of nodes which bear two spikelets. Thus this character, far from being an absolute difference, can be treated as a quantitative character. The same could be true of alternate vs. opposite leaves, 4-merous vs. 5-merous perianth, or any similar character.

In regard to the significance of the "hollow curve," the reader is referred to the review of Willis's book *The Course of Evolution*, by Sewall Wright in *Ecology*, 22: 345–347 (1941). Here Wright has pointed out that the "hollow curve" type of distribution would be expected for sizes of genera in a family if extinction and duplication of species balance each other, regardless of the manner in which species originate. This reviewer ventures to suggest still another basis for the "hollow curve," one which is purely selective. Anyone familiar with evolution realizes that evolutionary success is a relative affair. A group can be highly successful, moderately successful, or just successful enough to survive for a short period of time. Great success depends upon a series of fortunate coincidences. The group must be well adapted, with a genetically controlled mechanism of adaption which can be easily modified to suit a variety of different conditions. Also, it should be the first group to have developed its particular adaptive mechanism, or else its success would be diminished by competition with some previously established group. Third, it should have a large fund of genetic variability, and a reasonably high mutation rate. Finally, it should originate in some region of the earth from which it could easily migrate outward. A group originating on an oceanic island, no matter how well or broadly adapted, would have little chance of becoming large. This combination of favorable events would, of course, occur only rarely in the history of a family, so that large genera would always be few in number. Some of these conditions would be fulfilled in a larger number of instances, so that more genera of moderate size could come into being. And the number of combinations of characters sufficiently adaptive to permit their bearers to survive in a single ecological niche, or for a short period of geological time, is relatively large, so that a large number of small genera would be expected in any family. Hence Willis's "hollow curve," a generalization which should not be neglected in quantitative studies of evolution, can be explained in a number of ways, including one which supports the neo-Darwinian concept of natural selection acting on combinations of genes, each gene with a relatively slight effect on the phenotype.

Since *The Birth and Spread of Plants* is not a general treatise or a review of recent literature on plant evolution, its value depends entirely upon the validity of the theory which it attempts to support. In the opinion of the reviewer, this theory is completely mistaken, so that Willis's book, along with his previous volumes, should be relegated to the limbo of unproven and unprovable speculations.

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GENERAL BIOLOGY: PHILOSOPHY AND EDUCATION

GODS AND MEN. *A Testimony of Science and Religion. By Sir Richard Gregory. Stuart & Richards, London.* 12s. 6d. viii + 214 pp. + 8 plates. 1949.

ON BEING HUMAN. *By Ashley Montagu. Henry Schuman, New York.* $1.95. 126 pp. 1950.

Religion and ethics are commonly supposed to be quite closely related. It is therefore a matter of some

astonishment that two books can deal with these prime aspects of human life and yet succeed almost completely in avoiding contact. Indeed, they contrast sharply in virtually every respect. The book by Sir Richard Gregory deals specifically with religion in its historical aspects, whereas that by Ashley Montagu concerns social cooperation and avoids even the mention of religion. Moreover, the style of Sir Richard, who is frankly concerned with religion, is the clear, objective, largely factual, and a bit heavy style of the scientist; while the language of Ashley Montagu is that of argument not untouched with fervor. The former has forsworn the emotional quality of the religion he talks about, and the latter has become permeated by the spirit of what he eschews to mention.

The eminent author of *Gods and Men* has delineated in brief compass the relationships of science and religion through the ages. It is an interesting and a stimulating study, but one nevertheless limited and considerably biased. The author's scientific interests have narrowed his view almost exclusively to the relations of religion to astronomy, the physical sciences, and technology. The impact of Darwinism upon religious thinking is scarcely mentioned, and there is no real analysis of its implications. The supposed clash of social ethics with the nature of evolution is comprehended no whit more fully by Gregory than it was in the famous Romanes lecture of Thomas Henry Huxley in 1893. In fact, Sir Richard (like Sir Arthur Keith so recently, *Q. R. B.*, 23: 48, 1948) has once again evoked the specter of war as an agent of natural selection, ruthlessly sifting the peoples of the earth (pp. 164, 199). That there is another side to this may be seen in the book by Ashley Montagu.

The problem discussed by the latter is that of the dominating force in human nature: the thesis, that cooperation, rather than competition, has been the outstanding feature of progressive evolution. The social bonds, from their primary origin in sexual reproduction and family care, and long before the human species itself existed, have been the definitive characteristic of the "survival of the fittest," even more than has a "struggle for existence," interpreted in the conventional sense. This idea, as Ashley Montagu recognizes, is by no means novel. It was discussed extensively by Kropotkin and others before 1900. It this country, Lester Ward and Henry Drummond (one might well add, John Fiske and John Dewey) strongly emphasized the importance of cooperation in evolution. The work of the modern ecologists, including Allee, Emerson, and many others, has amassed a great weight of evidence to support the view that animal aggregation and social organization are preponderant factors in survival and differential reproduction. However, the blunt conclusion that "... the nature of life can be expressed in one word, co-operation" seems to push the matter to extremes.

The second part of the book applies this point of view to man. The argument is often eloquent and persuasive, yet may be thought to be dogmatic and to rely overmuch upon the authority of theorists like Freud, Adler, Fromm, and Burrow, rather than upon fully demonstrated and scientifically validated conclusions. The book concludes with a chapter on The Improvement of Human Relations through Education. Man needs "a change in attitudes of mind which must be based on the principle of co-operation, the principle of love ...." This is to be accomplished by adding to the three R's of conventional education "The Fourth R," the science of human relationships. By "social engineering" our society can be rebuilt "in terms of human values in which human relations are given a chance to function as they should."

One may perhaps be pardoned for not being sanguine. After all, this has been precisely the goal and endeavor of the greatest and noblest exponents of religion for some thousands of years. It is encouraging to see scientists, too, awakening to the need for the regeneration of society, if it is not too late. If the gods have not already departed from our midst, then the cooperation of scientists, teachers, and religious prophets may be able to accomplish more than the latter could achieve by themselves in bringing about the brotherhood of man. In this ultimate hope Sir Richard Gregory joins with Professor Montagu.

BENTLEY GLASS

THE LEGACY OF MAIMONIDES.

By Ben Zion Bokser. Philosophical Library, New York. $3.75. x + 128 pp.; ill. 1950.

Moses ben Maimon, the great medieval religious philosopher, made within Judaism an attempt similar to that which St. Thomas Aquinas was to undertake somewhat later in Christianity. Maimonides tried to reconcile biblical faith in revelation with Aristotelian rationalism. This little book is a philosophical discussion of Maimonides. It omits all his many other varied interests, like law and medicine. Even in the strictly philosophical field its omission of background is somewhat frustrating. Maimonides was a very wise man, and one can enjoy and respect him without agreeing with the author's "Back to Maimonides" orientation.

ERWIN H. ACKERKNECHT

SCIENCE AND CIVILIZATION.

Edited by Robert C. Stauffer. University of Wisconsin Press, Madison. $2.50. xvi + 212 pp. 1949.

This volume presents a number of essays, delivered at a symposium celebrating the 100th anniversary of the University of Wisconsin, and designed to discuss certain aspects of the problem of science and civilization. It

includes a paper by Richard P. McKeon on Aristotle's contribution to science; one by Lynn Thorndike on the transmission of knowledge during the Middle Ages; two rather philosophical disquisitions, by Max Black and Ernest Nagel, respectively, on the scientific method; a discussion of physics and culture, by Philip LeCorbeiller, and focussed on the Harvard program of general education; an excellent essay by Owsei Temkin on Metaphors of Human Biology, and discussions of science and society by Farrington Daniels and William F. Ogburn.

In the eyes of the reviewer, only three of the essays have direct reference to the topic with which the book purports to deal. The majority fail to approach even a phase of a facet of an aspect of it, to use the modern jargon. Whether this is the fault of science or of civilization or of both is a subject for symposia far more profound than this one. It is not the fault of the authors, and the book is highly recommended, since these are all good men with much to say and who say it well. Some of them, however, have said it better in other circumstances. I am vaguely reminded of a comment in a recent article in *Punch* by G. D. R. Davies which says, in a different kind of context, of *King Solomon's Mines*, "There is no evidence that [it] was written in the train, but on the other hand there is no evidence that it was not."

JANE OPPENHEIMER

THE EXPLANATION OF LIFE. *The Real Background to Nature.*

By Stephen Th. Bornemisza. Rascher Publishing House, Zurich, Switzerland. Sw. fr. 5.60. 269 pp. 1949.

If I understand him correctly, Stephen Bornemisza—geophysical engineer and former student of Max Planck—is concerned with the problem (if there is one) that while physical systems react only to forces operating directly on their surfaces, organisms on the other hand seem to react, especially in adaptive behavior, to their whole environment, present and future. To account for this alleged difference, he introduces the notion of *organic image*: "... an energetical image of the environment is projected through its [the organism's] surface, thus causing a real reproduction of the environment, like an image, in its interior." Furthermore, "... the entire organic structure constitutes an image," and "... organism and image are space-temporally equivalent with regard even to their confines." There is, then, an isomorphy of structure in organism and environment, and since an organism behaves according to its structure, it behaves according to the structure of the environment. Bornemisza's book is an elaboration of this view.

It is not likely that this new concept will prove to be a fruitful one in biology. For one thing it lacks the syntactical determinacy that characterizes a useful concept: it is not clear, for example, whether images are properties of organisms, or relations between their parts, or whether images and organisms are identical things, as the quotations given seem to indicate. If the latter is the case, then if Bornemisza's purpose is to explain the properties of organisms in terms of the properties of images, he has adopted the unhappy procedure of calling upon the properties of organisms to explain the properties of organisms.

Nor will biologists feel comfortable about his proposal to use the word "living" in such a way that it would be correct to say that everything is alive. Objections aside, it is astonishing that Bornemisza should propose this, since it is just precisely the differences between living and non-living systems that he has set out to explain. Instances of this sort are too numerous in this book.

JOHN R. GREGG

OUTLINE OF A METAPHYSICS. *The Absolute-Relative Theory.*

By Franklin J. Matchette. Philosophical Library, New York. $3.75. xiv + 108 pp. 1949.

This is a metaphysical speculation on the Unknown. Machette succeeds in describing it in unknowable terms.

DAVID B. TYLER

THE UNITARY PRINCIPLE IN PHYSICS AND BIOLOGY. *By Lancelot Law Whyte. Henry Holt and Co., New York.* $3.50. xxvi + 162 pp. 1949.

This is an extremely difficult book for the layman to read with profit. First, it is the final work in a long series which leads to the author's conclusion a step at a time. Second, the author does not address the layman, but the specialist in advanced modern physics. Finally, the author is addicted to an esoteric metaphysical jargon, like that of philosophers who wish to obfuscate their meaning.

It is probably unavoidable to express abstruse thoughts in abstruse language. The author has consequently devoted one complete chapter to defining his terms. Yet it must be confessed that his definitions contribute very little to dissipate the verbal smog in which his ideas are enveloped. I do feel that the smog is entirely verbal.

The author's thesis is approximately as follows: In those days when a single mind could comprehend all human knowledge, there was no science in the present sense. Instead, an aggregate of belief was accepted upon authority. The birth of science was also the birth of scientific specialization. Thus Science has never been unified, but only a group of related yet dis-

tinct individual sciences, the integration of which is not likely to be achieved by the scientists themselves—who are too close to their work.

The integration of science has been attempted, however, by a group of scholars whose names are not likely to be familiar to scientists, and a chapter is devoted to a discussion of their contribution to modern thought, a contribution which is rather like an expansion of the second law of thermodynamics beyond the limits of modern physical science.

If we have 2 masses of water, for instance, and know the temperature of each, we can prophesy accurately what mass and temperature will result from combination of the two into a single homogeneous mixture. But we cannot reason backward from the end result, and demonstrate the temperatures of the 2 component masses from a knowledge of that of the mixture. In other words, an effect can be deduced from a cause, because a cause always has the same effect, but any given effect may be derived from a number of sets of causes. Still, a composite number can have but 1 set of *prime* factors, and similarly any phenomenon in either the organic or the inorganic realm can have but 1 set of *prime* causes. In the case of the quantity of water of known temperature the prime causes are a finite number of molecules plus a finite number of quanta of energy. If these are symmetrically distributed, the quantity of water will be homogeneous, but if not, it will be heterogeneous, with different temperatures in different places. Since such a mixture will tend to become homogeneous by diffusion, the conclusion is drawn that in all phenomena of change there is a transition from an asymmetrical to a symmetrical state. A crystal is symmetrical; a living cell is asymmetrical. Life is a characteristic of asymmetrical conditions, for when an asymmetrical organism achieves perfect symmetry no more change occurs, and therefore it has no more life. Students of thermodynamics express the same thought in different language: where change takes place there is an increase of entropy. Does this mean that the universe is like a clock running down, someday to reach a state in which there can be no more action and therefore no life? The author does not commit himself on this point. He admits that such a conclusion is not unreasonable. A static universe is not impossible, but neither is it inevitable. A study of life may or may not indicate an eventual state in which all motion will cease, but the author is not making a study of life. He is making a study of the physical properties of living matter, and what he learns points to the eventual cessation of all motion, just like the study of the physical properties of inert matter. If this is not a divine event it is at least far off, and one toward which the whole creation moves. It therefore affords a basis on which the sciences can be unified.

PATTERNS OF LIFE.

By Alan Dale. William Heinemann, London, Melbourne, and Toronto. Library Edition, 12/6d.; Educational Edition, 7/6d. xii + 338 pp. + 8 plates; text ill. 1949.

It is the author's contention, and who can dispute it, that biology loses much of its savor unless a good dash of natural history is added to the usual course of laboratory studies. The earlier this aspect of biology is added, the greater are the responses and the rewards, since the formative years are so full of curiosity. The book takes its title from the patterns of life exhibited by various familiar plants and animals, and its intent is to provide the means whereby a student, on his own or as part of a class, can acquaint himself with what goes on in the biological life of field, wood, and stream. The student addressed is the teen-ager. Relatively little knowledge is assumed on the part of the reader, and the text is handled in a readable, informative, and interesting manner. As might be expected, familiar forms are stressed, a large portion of the book being devoted to the study of insects. The mammals and birds suffer neglect, while the commoner plants are treated briefly. Although written for English school children, with examples largely drawn from local habitats, the suggestions as to methods of observation and collecting are applicable under any circumstances and in any locality.

C. P. SWANSON

IF YOU COULD SEE INSIDE.

By Marie Neurath. Chanticleer Press, New York. $1.50. 32 pp.; ill. 1949.

I'LL SHOW YOU HOW IT HAPPENS.

By Marie Neurath. Chanticleer Press, New York. $1.50. 32 pp.; ill. 1949.

For the curious child who would take nothing for granted, these two pictorial books provide diagrammatic views of the structure and action of many of the more common things around us. The many examples include natural phenomena, as well as man-made structures and machines. Each book is complete in itself, and the illustrations are self-explanatory although a brief story accompanies each one.

BIOLOGY: HISTORY AND BIOGRAPHY

THE PERSONALITY OF WILLIAM HARVEY.

By Geoffrey Keynes. Cambridge University Press New York and London. $1.00. 48 pp. + 8 plates. 1950.

This small book represents the Linacre Lecture, delivered in 1949, which concerned itself with the

personality and the portraits of William Harvey. Geoffrey Keynes is the one contemporary writer whose work can be depended on to show the happiest combination of accuracy, enthusiasm, and imagination in the presentation of historical material. This small volume, in itself a portrait of Harvey in the broader sense, meets his usual standards. It is recommended not only as a charming commentary on Harvey, but also as an example of what medical biography can be at its best.

JANE OPPENHEIMER

JAN INGENHOUSZ—PLANT PHYSIOLOGIST, *with a History of the Discovery of Photosynthesis. Chronica Botanica, Volume 11, Nos. 5/6.*

By Howard S. Reed. Chronica Botanica Co., Waltham, Mass. $3.00 (paper). Pp. 285–396 + 9 plates. 1949.

This booklet is for the most part a reprint of the English edition of 1779 of Ingenhousz' classical work dealing with photosynthesis, *Experiments upon Vegetables.* The annotator, the Late Professor Reed, has added comments to many sections of the original text in order to indicate the influence of Ingenhousz' work on modern developments in the study of photosynthesis. The protocol of the experiments has not been included; and some sections of the French edition of 1787 are reproduced. In addition, a biographical sketch of Ingenhousz, as well as some reflections on the stage of scientific thought and progress of his era, are presented. This account, as well as the illustration, may be of interest to the biological historian, and to those interested in the early history and development of photosynthetic studies.

ALVIN NASON

CHARLES DARWIN'S AUTOBIOGRAPHY, *with his Notes and Letters Depicting the Growth of the Origin of Species.*

Edited by Sir Francis Darwin; with an introductory essay, "The Meaning of Darwin," by George Gaylord Simpson. Henry Schuman, New York. $3.50. 266 pp. + 1 plate. 1950.

Those who have not the patience or time to read the 2 volumes of Charles Darwin's *Life and Letters* will find this attractive, small volume of selections from it a good substitute. It includes the Darwin "Autobiography," Sir Francis Darwin's "Reminiscences of My Father's Life," and letters selected to show the growth and development of the Theory of Natural Selection and the Origin of Species in the mind of Darwin. The brief but excellent introductory essay by G. G. Simpson acquaints the reader with the place of Darwin's thought in current evolutionary thinking.

BENTLEY GLASS

A HISTORY OF HORTICULTURE IN AMERICA TO 1860.

By U. P. Hedrick. Oxford University Press, New York. $7.50. xiv + 551 pp.; ill. 1950.

The name of Ulysses Prentiss Hedrick immediately brings to mind the set of 6 quarto volumes, copiously illustrated in color, on the fruits of New York. Students of botany will also think of his edition of Sturtevant's *Notes on Edible Plants*, of his *History of agriculture in the State of New York*, and of his *Cyclopedia of Hardy Fruits*. In all, Hedrick has published some 16 volumes in his chosen field of horticulture. Those who have looked upon these books as classics may well be surprised at Hedrick's publishing a book in 1950, since he retired as Director of the New York State Agricultural Experiment Station a dozen years ago and is now in his eighty-first year. *The Grapes of New York* he published as early as 1908. Now, in his retirement, he has written a history of horticulture which will be our standard for the period it covers.

While the author has not scorned to use what secondary sources are available, he evidently found them to be so inadequate that he could get but little help from them. The history gives the effect of having been composed almost entirely from primary sources which Hedrick seems to have been very skillful in locating. Perhaps he has been accumulating material for this volume over a period of many years. Certainly no one else has his familiarity with the field. He has sifted thoroughly not only the publications of agricultural and horticultural societies, but also a great many travel books whose horticultural contents are often only incidental. Advertisements of some of the early nurserymen were a rich source, as were many of the published letters of prominent colonial citizens.

The book is divided into 3 parts. The first 144 pages deal with Indian gardens and colonial horticulture. Then 255 pages cover the post-Revolutionary period to the time of the Civil War. The third part deals with botanic explorers and botanic gardens, the dawn of plant breeding, and horticultural literature and horticultural societies. There is a bibliography of over 200 titles and an adequate index. The whole is an excellently written, clear, and complete treatment of a most important period of horticulture.

We would like to wish Dr. Hedrick many more years in which to write many more books.

CONWAY ZIRKLE

DISCOVERERS FOR MEDICINE.

By William H. Woglom. Yale University Press, New Haven; Geoffrey Cumberlege, Oxford University Press, London. $3.75. x + 229 pp. + 8 plates; text ill. 1949.

The history of medicine is one of the most brilliant facets in the general panorama of the development of

the arts and sciences through the ages. That brilliance is not in the least dimmed by the contributions of people who were not doctors.

In this delightful volume, the author has paid tribute to a number of such persons, including the singer who invented the laryngoscope; the clergyman who first investigated the phenomenon of blood pressure; the postmaster who cured his own deafness by designing and using an apparatus for catheterizing the eustachian tube; the priest who investigated the patterns of heredity; and the farmer who discovered the cause of the dreaded "milk sickness," to mention just a few. In reading the volume, one is impressed with the fact that these amateur scientists, working with painstaking care, continued their researches in spite of the disheartening opposition offered by time-honored tradition, and went on to make brilliant contributions in their many lines of endeavor with no thought of reward other than that of being of service to mankind. Like other pioneers, many of the early discoverers for medicine were ahead of their time, with the result that some of the truths they established were not accepted until they were "rediscovered" generations later.

Here is entertaining and enlightening reading not only for the medical profession, but also for that segment of the general population which harbors more than a casual interest in the history of science and medicine. A bibliography and an index are appended.

B. AUBREY SCHNEIDER

LORD LISTER. *His Life and Doctrine.*
By Douglas Guthrie. The Williams & Wilkins Co., Baltimore. $3.50. viii + 128 pp.; ill. 1949.

Lister's discovery of antiseptic treatment marks the beginning of a new epoch in surgery. Lister's accomplishment is due to the fact that he was as much a practical scientist as he was a surgeon, and able to grasp the practical implications of Pasteur's germ studies at the very beginning. Last of the great English Quaker doctors, he had a most attractive personality. This is a short chronological report on Lister's life and work. It has excellent illustrations.

ERWIN H. ACKERKNECHT

ECOLOGY AND NATURAL HISTORY

THE NATURE OF NATURAL HISTORY.
By Marston Bates. Charles Scribner's Sons, New York. $3.50. 309 pp. 1950.

Since the author is, by his own statement, "an orthodox research scientist with frustrated teaching instincts, trying to instruct anyone who can be persuaded to read this book," and since most of it was written in Villivicencio, Colombia, with a minimum of reference material available, it is not surprising that the outcome is something of a mildly pleasant textbook of biology, without the detailed anatomy, embryology, physiology, genetics, or illustrations that ordinarily make a textbook's nature obvious. As is usual of textbooks in *biology*, this one is from a zoologist's hand. Fortunately, Bates has traveled more than many zoologists, and speaks with a fine background of experience when he deplores generalizations based on the temperate zone only. "I think that no naturalist who has worked in the tropics can doubt the reality of concealing coloration . . . temperate zone biologists, particularly if they spend most of their time in the laboratory, are able to shrug this off as an interesting but unimportant phenomenon, an accident of convergent evolution, a result of the operation of some irrelevant physiological process . . . But such a biologist is badly shaken when one leaf on a branch he is holding starts to walk away; when a flying butterfly that he has been trying to catch simply disappears, though he could swear he saw the exact spot where it lit; when a patch of lichen on a tree gives him a severe burn and begins to crawl." And again: "Unfortunately for the advance of science, mimicry is a phenomenon that is most conspicuous in the tropics, where research is almost entirely on an observational level. If these striking mimicking butterflies occurred in the vicinity of some of our leading universities, we would know a great deal more about the phenomenon, because it would become the subject of experiment and of the collection of statistical data." And again: "This [annual rhythm conditioned by reproductive behavior] is true even in the tropics . . . The whole subject of bird movements and bird behavior in the tropics has been inadequately studied . . . About 85 per cent of the different kinds of birds are purely tropical, while almost 100 per cent of the ornithologists have habitats that range but little south of Miami, Florida."

Some of the comments have happy freshness: "The Museum of Comparative Zoology, at Harvard, was a fine building for its day; but now it is perhaps best characterized as a firetrap." "The woods are full of neo-Darwinians, anti-Darwinians, Lamarckians, Bergsonians, orthogenicists, and goodness knows what else, all with theories to sell, mostly wrapped in almost impenetrable layers of verbiage. The core, when finally arrived at, usually looks to me like metaphysics . . ." "The great figures of science have often been very practical men, intersted in practical problems. In biology, aside from the physicians, we have men like Anthony van Leeuwenhoek who was a mechanic (as well as a linen draper), grinding his own lenses, as much interested in the manufacturing problem as in the tiny animals that he discovered with his product. Louis Pasteur is the archetype of the practical man pushing ahead the theory of science, because Pasteur started always with a definite, practical problem . . . even though he might end with a grand and fruitful general theory." "What is the progress represented by the

radio if, when we turn it on, we hear only the same ranting demagoguery that, a century ago, we could have heard by attending the town meeting? The airplane takes us from New York to Paris in a day: but we must spend a week collecting the visas, certificates, permits, the endless pieces of paper necessary for the trip. In 1910 it took ten days or so to travel to Paris, but the bureaucrats had not yet thought up their complicated methods of utilizing paper or of wearing out the nervous resources of the prospective traveler."

Bates recognizes the chip placed on his shoulder in outspoken comment. "All of my colleagues will read this book (not for information, but to find what mistakes I have made—I do the same thing with their books). . . ." We consequently wonder why Allen, Allee, and Yerkes rate the title Professor, Libbie Hyman is the only Miss in the book (the rest are mentioned only by surname, or by given name and surname), and why Professor Brues, with whom Bates was associated at Harvard, is Charles Brues in one chapter, when he signs himself "C. T. Brues" and his close friends and his wife call him "Tommy."

LORUS J. & MARGERY J. MILNE

THE LIFE STORY OF THE FISH. *His Morals and Manners.*

By Brian Curtis. Harcourt, Brace & Co., New York. $3.75. xii + 284 pp. + 6 plates; text ill. 1949.

Few popularly written books could compare with the first edition of *The Life Story of the Fish* (*Q. R. B.*, 13: 468. 1938). The extensively revised, expanded and rewritten version is even better. New knowledge of the homing of salmon, the spawning of tarpon, the dynamics of fish populations, and of the mutual relations of men and fishes has been included. The chapters on the senses and behavior, on the air bladder, on reproduction and growth, and on habits and adaptations are absorbing as well as accurate accounts. Suffice it to say that the book will truly educate the fisherman and fish-lover in regard to the general structure and physiology of fishes as well as their ways. Special attention is given to trout and salmon and to other game-fishes. An excellent selection of references, arranged by chapters, has been added at the end of the book for the reader who may want to go farther into some phase of the subject of fishes. In any case *The Life Story of the Fish* makes the best of beginnings.

BENTLEY GLASS

A CONSERVATION HANDBOOK.

By Samuel H. Ordway, Jr. The Conservation Foundation, New York. $1.00. 76 pp. 1949.

The Conservation Foundation of New York is an organization sponsored originally by the New York Zoological Society, but now receiving support from various other sources as well. Under the leadership of Fairfield Osborn, its personnel consists of men who, with a respectable record of achievement in business and the professions, prefer to work for conservation, if possible.

To date this group has used its resources to carry out a number of valuable projects, of which the present handbook is one. In clear and simple language this gives the basic ideas that are important in conservation, being in effect a glossary organized on a topical basis. Essentially it deals with the renewable resources —soil, water, vegetation, and animal life—although in a lucid sentence it states the problem of non-renewable resources.

Being compact and highly selective, the little book is likely to tempt any intelligent reader to think of his own revisions and expansions. In other words, Ordway is stimulating as well as informative. Writing for the novice, he intrigues the initiate—a rare thing. The book is attractively made and served by an excellent index, annotated as necessary.

PAUL B. SEARS

CONSERVATION OF NATURAL RESOURCES.

Edited by Guy-Harold Smith. John Wiley & Sons, New York; Chapman & Hall, London. $6.00. xii + 552 pp. + 1 plate; text ill. 1950.

This book is, despite its title, a revision of *Our Natural Resources And Their Conservation* (1936), by Parkins and Whitaker, with some shift in emphasis on chapters and subject matter. One completely new and needed topic has been introduced, Fisheries for the Future, while a considerable improvement has been made in several chapters, notably those dealing with soil and game. In general, the original work has been modernized through revision of tables and additional supporting data, through indicating the progress that has been made, and through the use of considerably more illustrative material—some thirty figures.

Lack of accord among authors is to be found in certain instances, as in the opinions regarding forest-runoff relationships, subordination of watershed protection values to engineering structures, and a few others, while little or nothing is reported about the promising development in game work, the farm-game program. As in the original book, no opportunity has been taken to make the subject matter coherent and to show the "oneness" of the conservation problem. Although the earlier textbook served well, it appears that the abundant and able talent represented here, including some twenty specialists, might well have taken a fresh approach rather than have worked so within the circumscribing limits of revision.

R. V. TRUITT

NEW BIOLOGY—8, 9.

Edited by M. L. Johnson and M. Abercrombie. Penguin Books, Harmondsworth, Middlesex; Allen Lane, Baltimore. 35 cents ea. (paper). (8) 128 pp. + 16 pl.; (9) 128 pp. + 8 pl. 1950.

The eighth of this series for the informed layman includes articles on Lysenko: the Scientific Issue (R. H. Richens); Maize in a Modern World (Gordon Haskell); Biological Control of Weeds (Frank Wilson); Processes of Fossilization (Gwyn Thomas); The Biology of Enzymes (D. W. Ewer); and Goethe as a Biologist (M. Abercrombie). The authoritative article on Lysenkoism is exceptionally fine; and the article on the biological control of weeds is sure to be profoundly interesting to all biologists not acquainted with recent work along these lines.

Number 9 includes articles on the causes of cancer (I. Berenblum); animal conservation in Canada (W. Rowan); butterfly migrations (C. B. Williams); dispersal of insects by wind (C. G. Johnson); phosphorus drugs and insecticides (B. A. Kilby); the male fern (C. W. Wardlaw); and recent whale findings (R. F. Ewer). An important addendum is the UNESCO Statement by Experts on Race Problems. As usual, the topics are ably handled in a simple but informative manner, with a minimum of technical jargon.

EVOLUTION

HISTORICAL GEOLOGY.

By Carl O. Dunbar. John Wiley & Sons, New York; Chapman & Hall, London. $5.00. xii + 567 pp.; ill. 1949.

INTRODUCTION TO HISTORICAL GEOLOGY.

By Raymond Cecil Moore. McGraw-Hill Book Co. New York, Toronto, and London. $5.00. x + 582 pp.; ill. 1949.

The first of these two textbooks conforms to the excellent standards established by its predecessor of the same title, which was first introduced by Charles Schuchert and then followed by a number of editions with Schuchert and Dunbar as co-authors. This latest book has been extensively revised with the addition of new illustrations as well as numerous changes in the text. The paleogeographic maps have been altered to conform with more recent geological knowledge and have been enlarged so that they are more easily read. Of particular interest to those who wish to use this as a textbook is the elimination of much of the stratigraphic detail present in the older editions, thus making the book easier to read and more interesting to the student.

The basic outline of *Historical Geology* is similar to that of the earlier editions. It begins with a series of introductory chapters that deal with the record as preserved in the rocks, the geologic time scale, fossils and evolution, and the origin of the earth. In the succeeding chapters each of the geologic periods is taken up, beginning with the Cryptozoic or Pre-Cambrian and continuing to the Cenozoic. A chapter is devoted to each period and includes a discussion of the physical history as well as the life known to exist at that time. The final chapters cover the Pleistocene ice sheets and the evolutionary history of the mammals, including man. At the end is a useful appendix which briefly discusses the general characters of the various phyla of the plant and animal kingdom.

In his *Introduction to Historical Geology*, Professor Moore has used a different approach to the subject than he did in his earlier *Historical Geology* (McGraw-Hill, 1933). The latter, which was presumably designed largely for advanced students, is larger and contains more detail, especially in regard to the subject of stratigraphy. His new textbook, on the other hand is shorter and was written primarily for beginning students.

The general plan of this book is similar to that of Dunbar's. It begins with a series of introductory chapters which deal with the methods used to determine earth history. The first chapter, entitled Materials and Methods of Historical Geology, contains an extremely useful discussion on the structure, texture, and other features of rocks, and the inferences that may be drawn from them. This also includes a section on fossils, how they occur, and their use in correlation; it concludes with a brief outline on the radioactive method of age determination, with the latest data on the age in years of the various eras and periods. The second chapter presents a general review of organic evolution and is followed by a chapter on the origin of the earth.

Most of this *Introduction to Historical Geology* is given over to the history of the earth since the beginning of the Cambrian with chapters on each of the periods. Moore's method of presentation is, however somewhat different from that of Dunbar's *Historical Geology*; each of the chapters on the different periods is taken up largely with a discussion of the physical history, and gives only a brief summary of the life of that time. The major part of the history of life is contained in three chapters covering the nature and evolution of Paleozoic, Mesozoic, and Cenozoic life, respectively. Such a presentation has the merit of permitting the student to get a more connected picture of the development of living organisms.

Moore has also used a different plan for his paleogeographic maps. One map is given for each of the different periods, and on each of these maps the most persistent seaways are shown in heavy shading, whereas the areas which were only occasionally submerged are shown in lighter shading. On the page opposite each of these is a map of North America showing the present outcrop distribution for the period under consideration.

Both of these books represent a substantial contribution and will be invaluable to those engaged in teaching the subject.

THOMAS W. AMSDEN

LOWER CRETACEOUS STRATIGRAPHY IN SOUTHEASTERN ARIZONA. *Geol. Soc. Amer. Memoir 38.*

By Alexander Stoyanow. The Geological Society of America, New York. $2.50. viii + 169 pp. + 24 plates + 3 maps; text ill. 1949.

The first part of this memoir covers in detail the stratigraphy of the Lower Cretaceous of southeastern Arizona. It is divided by Stoyanow into the following stratigraphic units: Lowell formation, at the base, containing in ascending order the following members: Pacheta, Joserita, Saavedra, Cholla, Quajote, Perilla, and Pedregosa. The Lowell formation contains three successive ammonite faunas of Caucasian-Transcaspian relationship: (1) the Parahoplitan fauna of the basal Pacheta member, which is unknown elsewhere in the United States; (2) the Dufrenoyan fauna, which ranges from the middle of the Joserita member into the Cholla member and is correlated with the Travis Peak *Dufrenoya* fauna of Texas; and (3) the Acanthohoplitan fauna of the Quajote member, which is also new for the United States. On the basis of his observations, Stoyanow infers that the Aptian portion of the Lowell formation contains no index fossils below the *Dufrenoya justinae* zone (Cholla member) which are common to the Texas section. Above the Lowell formation is the Mural limestone, containing *Orbitolina texana*, which is equivalent to the Glen Rose limestone of Texas. Isolated sections of Lower Cretaceous beds from other areas in Arizona are also discussed.

A more natural paleontological Aptian-Albian boundary is suggested by Stoyanow to occur between the *Immunitoceras nolani* and *Hypacanthohoplites jacobi* zones of the standard Cretaceous system.

The evolution of the Trigoniae is discussed in considerable detail, along with a comparison of them with species from other areas. The vertical distribution of index ammonites and Trigoniae throughout the Lower Cretaceous sequence permits an interpretation of the phylogenetic development of Trigoniae of the pseudo-quadrate and v-scripta-vau groups in relation to ammonite zones. Ontogenetic studies of the Trigoniae show the trend of appreciable changes in the pseudo-quadrate group from the Kimmeridgian through the Neocomian to the Aptian. However, certain Trigoniae of the v-scripta-vau group show remarkable morphological constancy from the Kimmeridgian to the Aptian.

In the second chapter of this memoir, Stoyanow describes 22 new species of pelecypods and 21 new species of ammonites, with four new genera, *Kazanskyella*, *Sinzowiella*, *Immunitoceras*, and *Paracanthohoplites*, and two new subfamilies.

ALFRED R. LOEBLICH, JR.

BIBLIOGRAPHY OF FOSSIL VERTEBRATES 1939–1943. *Geol. Soc. Amer. Memoir 37.*

By C. L. Camp, S. P. Welles, and Morton Green. Geological Society of America, New York. $4.50. vi + 371 pp. 1949.

This is the third in a series covering vertebrate paleontology from 1928 on. The main part of the volume comprises an Author Catalogue of 178 pages, a Subject Index of 47 pages, and a Systematic Index of 105 pages. A Supplementary List of Serials adds those journals lacking in the first two of the series; and a very useful Synopsis of Classification concludes the volume. This synopsis is based on the revisions of Berg for the Agnatha and Pisces; of Romer for the Amphibia, Labyrinthodontia, Pelycosaura, and Therapside; of Wetmore for the birds; and of Simpson for the mammals.

The authors have broadened the term "fossil" to include artifacts and other remains of early man, stopping with the arrival of the mesolithic. These inclusions should greatly widen the use of the volume.

As when looking at the superb volumes in the series *Bibliography and Index of Geology Exclusive of North America*, the impression of a poor biologist who looks at this model effort to render the vast literature of a scientific field readily accessible to search is a feeling of enormous envy.

BENTLEY GLASS

THE AUDITORY REGION IN SOME MEMBERS OF THE PROCYONIDAE, CANIDAE, AND URSIDAE. *Its Significance in the Phylogeny of the Carnivora. Bull. Amer. Mus. nat. Hist., Vol. 92: Art. 2.*

By Jean Ringier Hough. American Museum of Natural History, New York. $1.00 (paper). iv + pp. 71–118 + 7 plates; text ill. 1948.

This comparative study of modern and fossil members of the raccoon, dog, and bear families is particularly interesting because the author undertakes to discuss the genetic basis of the phylogenetic change in the Carnivora. It is concluded that the auditory region of the skull is more stable in evolution than the limbs and dentition, which underwent more adaptive radiation; and the auditory region therefore provides a more stable basis for classification. The occurrence in early populations of wide variability overlapping the later established procyonid, canid, and viverrid

types of auditory region makes it unwise, however, to carry present-day categories back so far as the Oligocene or even Miocene.

BENTLEY GLASS

PLEISTOCENE STRATIGRAPHY AND PALEONTOLOGY OF MEADE COUNTY, KANSAS. PLIOCENE SAW ROCK CANYON FAUNA IN KANSAS. *Cont. Mus. Paleontology, Univ. Mich., Vol. VII, Nos. 4, 5.*

By Claude W. Hibbard. University of Michigan Press, Ann Arbor. (4) 75 cents (paper); (5) 40 cents (paper). (4) pp. 63–90 + 1 plate + 1 map; text ill.; (5) pp. 91–105; ill. 1949.

Five successive Pleistocene faunas occur in the formations of Meade County, Kansas, ranging from the Deer Park fauna (near base of Meade formation) of Lower Pleistocene age, to the Jones fauna (Vanhem formation), very late Pleistocene.

The Saw Rock Canyon fauna, rich in fossils including a bone-eating dog (*Osteoborus progressus* Hibbard), 2 new species of heteromyid rodents, and 2 cricetid rodents, is close to but older than the Rexroad fauna (Blancan), and is placed in the upper Middle Pliocene or lower Upper Pliocene.

PREHISTORIC MAN: *The Great Adventurer.*

By Charles R. Knight. Appleton-Century-Crofts, New York. $5.00. xvi + 331 pp. + 21 plates; text ill. 1949.

Charles Knight, whose paintings of prehistoric life have done so much to make vivid to the modern imagination the ages of the dinosaurs, early mammals, and primitive man, has this time undertaken to accompany a series of pictures with his own text. The 21 plates are still his best contribution. The text itself is wordy and high-flown in style, and unfortunately contains many inaccuracies. Only in the vivid reminiscences of his own trip with the Abbé Breuil in 1927 to visit Les Eyzies and the cave of Altamira will the adult reader be likely to find an account which is genuine interest. The rest is presumably written for "teen-agers," who may, indeed, enjoy it.

BENTLEY GLASS

GENETICS, PALEONTOLOGY, AND EVOLUTION.

Edited by Glenn L. Jepsen, Ernst Mayr, and George Gaylord Simpson for the Committee on Common Problems of Genetics, Paleontology, and Systematics, of the National Research Council. Princeton University Press, Princeton. $6.00. xvi + 474 pp. + 1 pl.; text ill. 1949.

Those who were fortunate enough to be members of the Princeton Bicentennial Conference on Genetics, Paleontology, and Evolution in January, 1947, remember it as a high spot in their scientific experience. The book into which most of the papers given at the Conference have now been collected, together with some additions, will exert a much wider, if no deeper, influence on students of evolution. In this respect it may be likened to *The New Systematics* (1940), another book that marked significant new trends in biological thinking.

The volume contains 8 parts, each comprised of one or more related papers. In Part I, Geological Time, Adolph Knopf has evaluated the methods based on radioactive disintegration and has pointed out that only 3 out of 25 thoroughly reliable determinations relate to precisely dated geologic evidence: (1) 440 million years ago, late Cambrian; (2) 230 million years, and of Early Permian; (3) 58 million years, beginning of Eocene. Part II contains 5 papers. Curt Stern discusses the relations between Gene and Character, which are of such fundamental significance to evolution because of the fact that selection cannot act directly upon genes but must act on characters combined in entire individuals. Warren P. Spencer, drawing on his extensive work with *Drosophila hydei*, has considered anew the question of gene homologies between species. In spite of the fact that different genotypes may produce the same phenotypic facade, many sex-linked and some autosomal genes in *D. hydei* can be identified by multiple criteria as being homologous with those in *D. melanogaster*. The evidence afforded by fossil vertebrates, particularly the labyrinthodonts, on the nature of evolution is set forth by D. M. S. Watson in a profoundly stimulating essay; and this is followed by treatment of essentially the same topic by D. Dwight Davis. The latter approaches the subject, however, from a more historical point of view and is particularly concerned to analyze the influence upon scientific work in the field of evolution exerted by such concepts as evolutionary progress, morphological "types," and adaptation. This section is concluded by a brief paper by Theodor Just, like the last in viewpoint and emphasis, but devoted to plant morphology. In contrast to these, Watson was more interested in discovering whether orthogenetic trends and series could be interpreted in terms of adaptation and natural selection. This he concludes is indeed the case.

Parts III and IV deal respectively with Evolutionary Trends and Evolutionary Rates. These are not sharply separable, and the 7 papers may be considered together. Alfred S. Romer discusses Time Series and Trends in Animal Evolution, again emphasizing adaptation and selection as underlying "orthogenetic" trends, and adding a vigorous comment on the importance of parallel evolution and a plea for a more thorough consideration of extinction. T. Stanley Westoll's contribution on the Evolution of the Dipnoi is the most minutely docu-

mented paper in the book. It leads to significant conclusions about the different rates of evolution in the group in different geological periods, the Middle and Late Devonian having been marked by an extraordinary acceleration in the rate of change of the group. A brief paper by Horace E. Wood, II, on Evolutionary Rates and Trends in the Rhinoceroses shows that this group demonstrates evolutionary patterns, such a adaptive radiation, convergence, and a bushy family tree, quite as well or better than more well-known examples. Ralph W. Chaney points out that in the study of angiosperms such as *Quercus*, *Juglans*, and *Carya* one gets the impression of no evolution whatsoever since the Miocene if only leaves are examined; but the fossil fruits show more modification. It is important to collect and study fruits and seeds as well as leaves in studying rates of plant evolution. G. G. Simpson's paper deals with the methodology of studying rates of evolution in animals, and is an extremely important and valuable guide for all who would undertake such studies. G. Ledyard Stebbins, Jr., has made a comparison of rates and factors of evolutionary change in woody and herbaceous flowering plants, relating them to the concepts set forth by Simpson and Schmalhausen, and emphasizing the relation of the plant to the environment. One of the most interesting studies of evolutionary rates made to date is the paper of Bryan Patterson on the taeniodonts, whose evolution illustrates beautifully such concepts as temporary accelerations of evolutionary rates, "quantum" evolution (Simpson), phyletic evolution in different adaptive zones, and the like.

Part V deals with Speciation, and commences with a concise discussion of the principles involved, by Ernst Mayr. David Lack has contributed a summary of his studies of the Galápagos finches and the relation of the adaptive radiation they have undergone to the availability of ecological niches on the islands. E. B. Ford has contributed a paper on the early stages of allopatric speciation seen in certain British lepidopterans, including a study of fluctuations in the frequency of a particular mutant gene in a limited population of a few thousand moths. John A. Moore's summary of the geographic patterns of variation in N. American frogs (*Rana*) and William Hovanitz' equally interesting examination of the effects of natural hybridization in N. American butterflies (*Basilarchia* and *Colias*) together throw a great deal of light on the relations of adaptation and isolating factors. Herbert L. Mason has added an interesting note on the island pine, *P. remorata*, a relic species of Santa Cruz and Santa Rosa Islands off California. Another species, *P. muricata*, has in recent times extended its range down the coast and across to the islands, where it is actively hybridizing with *P. remorata* and absorbing it as a species.

Part VI, Adaptation, includes 2 papers. One by Sewall Wright, on Adaptation and Selection, is a most concise and valuable summary of his mathematical analyses of evolutionary processes. The other, by Edwin H. Colbert on progressive adaptations seen in the fossil record, is a further consideration of the interpretation of evolutionary trends in terms of adaptation and natural selection rather than orthogenesis.

The volume concludes with the popular lecture of J. B. S. Haldane on Human Evolution: Past and Future; and the final "redintegration" of the symposium, a well-written summary by H. J. Muller which itself introduces a valuable proportion of original critique and concept. There are further an extensive Glossary and a very adequate Index.

Among the numerous outstanding books on evolution published in the last two decades, this volume is unquestionably among the best. What it lacks in unity of style and subject, because of its diversity of authorship, it gains in force from the quickly apparent agreement in point of view which has been reached by so many leaders in the previously isolated fields of genetics, paleontology, and evolution. The highest praise that can be given is that a true synthesis of evolutionary theory is heralded and inaugurated in these pages.

BENTLEY GLASS

GENETICS AND CYTOLOGY

EXPERIMENTAL CELL RESEARCH. *Volume I, Number 1—January 1950.*

Edited by: Torbjorn Caspersson, Honor B. Fell, John Runnstrom, Francis O. Schmitt, Paul Weiss, and Ralph W. G. Wyckoff. Published under the auspices of The International Society for Cell Biology by The Academic Press, New York. Four issues yearly — $10.00. No. 1: 149 pp. + 14 plates; text ill. January 1950.

This is the first number of the first volume to be issued of the organ of the International Society for Cell Biology. This journal will publish papers and brief noted dealing primarily with experimental cytology, that is, with the experimental analysis of the activity, structure, and organization of the cell and its subunits. In view of the excellence of its board of editors and its high standards, as exemplified in the first number, of format, typography and illustrative reproduction, this periodical will form a welcome addition to the modern biological literature.

JANE OPPENHEIMER

EXPERIMENTELLE UNTERSUCHUNGEN ÜBER RONTGENEFFEKTE UND CHEMISCHE EFFEKTE AUF DIE PFLANZLICHE MITOSE.

By Kurt Hohl. Georg Thieme, Stuttgart. DM 6.— (paper). 87 pp.; ill. 1949.

Within the brief pages of this paper-bound volume, Hohl has summarized and compared the effects of x-rays and certain chemicals on the course of mitoses in root-tips. In so far as the summary goes, the review provides a reasonable picture of the experimental work which had been done up to the early 1940's; but a good deal of the more recent work, particularly that completed in this country, has been omitted. The difficulties of securing the recent literature in Germany account for the later omissions. The major portion of the review is concerned with the effects of chemicals on mitoses, and the reader is given a good review of those substances which affect the cytoplasm, the spindle, and the chromosomes. Included are discussions of certain European papers which are not readily available to workers in this country.

C. P. SWANSON

ADVANCES IN GENETICS. *Vol. III.*

Edited by M. Demerec. Academic Press, New York. $6.00. viii + 267 pp.; ill. 1950.

Even to the casual observer, Volume 3 of this series is far below the two preceding issues in quality and quantity. Delaporte's review of bacterial cytology contains little except that to which the author subscribes, or that upon which the author has worked. Horowitz has provided an excellent review on biochemical genetics, but it differs little from numerous previous reviews on the same subject. Lewis' article on position effect is also well handled, but it is unfortunate that it was written too soon to include McClintock's amazing work in corn. Richey's paper presents the past, and points out the future, of corn breeding in straightforward fashion, while Suomalainen's on parthenogenesis in animals, though complete and exhaustive, is equally dull and overlong. O'ven's article, however, has no place in a review volume of this sort. In the first place, it is not a review but on the contrary the development of a mathematical theory of gene recombination. As such, it should logically find a place in a research journal. In addition to this, its usefulness for the analysis of experimental data rests upon the user's willingness to accept Owen's primary assumptions. These premises have their origin in Mather's idea of a serial formation of chiasmata proceeding from the centromere distally, and in Darlington's cytological hypotheses. The important analysis of Charles, which places Mather's hypothesis in serious doubt, is not mentioned. The third volume is recommended only to those who wish to keep the series complete and intact.

C. P. SWANSON

GENERAL AND SYSTEMATIC BOTANY

BOTANICAL NOMENCLATURE AND TAXONOMY. *A Symposium Organized by the International Union of Biological Sciences with Support of UNESCO at Utrecht, the Netherlands, June 14–19, 1948. With a Supplement to the International Rules of Botanical Nomenclature, embodying the alterations made at the Sixth International Botanical Congress, Amsterdam, 1935, compiled by T. A. Sprague. Chronica Botanica, Vol. 12, Nos. 1/2.*

Edited by J. Lanjouw. The Chronica Botanica Co., Waltham, Mass.; Stechert Hafner, New York. $2.50 (paper). viii + 87 pp.; ill. 1950.

This small book is primarily the report of a symposium held in Utrecht in 1948 preliminary to the Seventh International Botanical Congress, then scheduled for July, 1950, in Stockholm. The principal objective of the symposium was to organize as effectively as possible the nomenclatural section of the Congress and to develop a mechanism for handling the large number of proposed changes to the International Rules of Botanical Nomenclature. Minutes of the meetings show that most attention was given to questions concerning these proposed alterations.

In Supplement I, J. Lanjouw called for the organization of an International Society of Plant Taxonomists. Supplement II gives a list of the members of the committees of the International Commission for Nomenclature. This is followed by an unnumbered supplement that gives the alterations to the International Rules voted at the Sixth International Congress.

REED C. ROLLINS

EVOLUTION OF PLANTS. *Second Printing.*

By Harvey E. Stork. Burgess Publishing Company, Minneapolis. $3.00 (paper). vi + 183 pp.; ill. 1949.

The title of this annotated laboratory manual is misleading, since it is essentially a survey of the plant kingdom from the simple algae to the herbaceous angiosperms. Any references to evolutionary trends are descriptive, and relate primarily to the reproductive structures. Genetic principles are not mentioned. The manual is useful only to students taking a survey course.

C. P. SWANSON

A BRIEF COURSE IN ELEMENTARY SYSTEMATIC BOTANY FOR GARDENERS.

By Harold Norman Moldenke. Published by the author (N. Y. Botanical Garden, Bronx Park, N. Y.); lithoprinted by Edwards Bros., Ann Arbor, Michigan. $2.00 (paper). 130 pp.; ill. 1947.

The series of lectures which the author gives as a science course for gardeners at the New York Botanical Garden has been lithoprinted as a paper-bound manual. To judge from the contents, the course must be an

extraordinarily complete one, with the vast terminology of systematics dealt with in great detail. After a lengthy introduction dealing with the derivation of terms and their use in the identification of structures, various families of plants are treated in brief, horticultural species being used almost exclusively as examples. There appears to be no rhyme nor reason to the order in which families are discussed, but to a horticulturist this is of relatively little importance. The student is given a brief introduction to evolutionary principles as they apply to the monocots and dicots in general, but this is not integrated as a guiding principle with the treatment of specific families. The volume is terminated with a number of tests which will give the reader an idea of what the author expects them to know. The only criticism which can be made is that the smallness of the print is such as to make reading difficult and very tiring.

C. P. SWANSON

LAND PLANTS COLLECTED BY THE VELERO III, ALLAN HANCOCK PACIFIC EXPEDITIONS 1937–1941. *Vol. 13, Number 2.*

By Howard Scott Gentry. University of Southern California Press, Los Angeles. $3.25 (paper). 245 pp. + 15 plates; text ill. 1949.

The work of the Allan Hancock Pacific Expeditions of 1937–1941 was devoted primarily to marine biology, and its collections were mainly of marine animals. Nevertheless, approximately 2100 specimens of land plants were collected at widely scattered localities, extending from the Channel Islands of California to the coast of Costa Rica. The present paper is a report on these botanical collections. The author recognizes four major floristic elements in the collections as a whole: the "California flora," related to the Mediterranean type of climate; the Sonoran Desert flora; the Sinaloan subtropical flora; and the Central American tropical flora.

The plants are not put together in a single catalogue, but are gathered into 7 separate lists which represent geographic regions. These regions are as follows: the Channel Islands of California; Cedros and San Benitos Islands; Revilla Gigedo Islands; Tres Marias Islands; California Gulf region; Jalisco and Oaxaca in Mexico; and Costa Rica. Preceding the catalogue for each of them is a "general discussion of the physiography, the climate, and the plant geography with special emphasis on the historical or developmental aspects of the flora involved." In each case there is also a brief review of previous botanical work, and an appended list of the cited literature.

Three new species are proposed in the book, and 7 new nomenclatorial combinations. There are 15 plates, 3 of which contain line drawings of plants, while the remainder are halftone photographs of plants and types of vegetation. There is an index to plants, localities, and collectors. A table in the introduction gives collection localities and dates, the names of the collectors and their collection numbers, and the approximate numbers of specimens taken at each place.

The material is clearly presented, and the work appears to have been carefully done. It might well stand as an example of the proper and intelligent use of small, geographically scattered collections. Instead of merely identifying and publishing them as the usual appended byproduct of some larger work, the author has taken the trouble to place them where he thinks they belong in the total floristic and phytogeographic context of North and Central America.

HUGH M. RAUP

FLORA OF ILLINOIS, *Containing Keys for Identification of the Flowering Plants and Ferns. Second Edition. The American Midland Naturalist, Monograph No. 5.*

By George Neville Jones. The University of Notre Dame Press, Notre Dame, Indiana. $4.25. vi + 368 pp. 1950.

The 2nd edition of Jones' (1st Ed., *Q.R.B.* 21: 82. 1946) manual has made possible some needed revisions, with improvements in a few of the keys, nomenclatorial changes, and the addition of 73 species. The author remains conservative in nomenclatorial matters, refusing to take up agglutinated common names, and hesitating to dispense with Latin specific names that from long usage are well known.

HUGH M. RAUP

FLORE DU CONGO BELGE ET DU RUANDA-URUNDI. SPERMATOPHYTES. *Volume I.*

Comité exécutif de la Flore du Congo Belge et le Jardin Botanique de l'État. L'Institut National pour l'Étude Agronomique du Congo Belge, Brussels. 300 fr. belge (papier ordinaire); 500 fr. belge (papier mince). viii + 446 pp. + 12 plates; text ill. 1948.

Initiated in 1942 at the invitation of the I. N. É. A. C. by an Executive Committee, the *Flora of the Belgian Congo* is planned in four major sections, for the spermatophytes, pteridophytes, bryophytes, and thallophytes, respectively. A general introductory volume is to contain an account of the botanical exploration of the region and of the study of the Congo flora, as well as of its phytogeographical areas and plant communities. The Executive Committee, charged with the execution of this vast project, is composed of 11 members (two deceased) and headed by W. Robyns, Director of the Botanical Garden in Brussels. The present volume marks the beginning of the large venture and, because of its general excellence, is testimony of careful planning on the part of the Executive Committee and a guaran-

tee that future volumes will be of equal standard. *Spermatophytes, Vol. 1,* contains the treatment, prepared by 11 contributors, of 4 gymnosperm and 17 dicotyledonous families (introduced families such as the Casuarinaceae and Cannabaceae are included in small type but not numbered in regular sequence). Some examples may illustrate this cooperative plan. The Moraceae occupy pp. 52–175 and are credited to L. Hauman, whereas the genus *Ficus* with its 93 species is treated by J. Lebrun and R. Boutique. The Loranthaceae, represented by 2 genera and contributed by S. Balle, occupy pp. 304–380. Of these pp. 305–373 are needed for the 67 species of the genus *Loranthus*, whereas the remainder is used for the 7 species of *Viscum*. The subgenera of *Loranthus* appear mostly with names proposed as new combinations, as do various species of this genus. Two species, *Loranthus erianthus* and *L. cornetii*, are shown on a beautiful color plate, whereas other species of the same genus are illustrated by excellent line drawings. Throughout the flora, keys to genera and species are given and, as far as available, detailed descriptions, distribution, habitat, common name, uses, and other observations are provided for every species. Only types and specimens of rare and critical species are cited. The color frontispiece illustrates an African cycad, *Encephalartos laurentianus*. In general, the Engler system is followed, although the Dicotyledones come immediately after the gymnosperms. As far as possible, the International Rules of Botanical Nomenclature have been observed. In view of the large number of species and varieties of flowering plants known from this area at the end of 1940 (10,797), some 20 volumes will be required for this part of the *Flora*. As the ferns and other groups are studied, the number of volumes of the *Flora* will be considerably increased. Thus, if completed within the next twenty years or so, this monumental *Flora* will be one of the most important modern works to deal with a large tropical flora, and it will be an indispensable source of information far beyond the geographical limits its covers.

THEODOR JUST

PLANT MORPHOLOGY

THE NATURAL PHILOSOPHY OF PLANT FORM.

By Agnes Arber. Cambridge University Press, New York and London. $5.00. xii + 245 pp.; ill. 1950.

The author, a distinguished botanist, is best known in general for her historical work, *Herbals*, although her fellow botanists have long appreciated her other, more technical books, such as *The Gramineae*, and *Monocotyledons*. The present work is a study of the morphology of the higher land plants or cormophytes. The term morphology is used in a very broad and inclusive fashion, and it is understood as including the description and interpretation of the entire external and internal organization of the plant from the beginning to the end of its life-history. The function of morphology is held to be "to connect into one coherent whole, all that may be held to belong to the intrinsic nature of a living being." Indeed, among plants, "form" may even include the analogue of behavior in the animal field. An animal may act without altering its form but the only modes of action in plants, with a few notable exceptions, are either growth or the discarding of parts, both involving changes in form.

Morphology thus broadly considered has a most ancient and honorable history, which the author traces in sufficient detail for her purposes. Beginning with the morphology of the Aristotelian school, the general concepts are followed in the works of St. Albertus Magnus and Andrea Cesalpino, and later, in the works of Jung, Goethe, and their contemporaries, to the early 19th century contributions of deCandolle. Particular attention is paid to pre- and post-Darwinian morphology. The whole is brought up to date by discussions of our current ideas on the subject.

This is an extremely difficult book to evaluate. There is no question of the author's learning or the accuracy of her presentation, or of her judgment in picking out and emphasizing the more important aspects of the subject. Perhaps I should state simply that I disagree with her basic philosophy, particularly in the final chapter where Arber discusses in detail the relationship of mechanism and teleology. Her treatment of the material, efficient, final, and formal causes seems faintly archaic. When she writes, "When the general principles of biology are in question, we find, even today, that Aristotle can often give us more fundamental help than any writer of a later date," the reviewer just does not believe it.

This suggests a very definite omission in the author's discussion of teleology. Inasmuch as natural selection also explains those phenomena of adaptation generally cited as evidences of teleology, it provides us with a second and competing hypothesis, and the two hypotheses were not both developed and compared with each other by the author. An unwanted hypothesis cannot be disposed of simply by ignoring it. Natural selection was used anciently as an alternative explanation to teleology by Empedocles, Epicuros, and Lucretius. Even Aristotle recognized that it competed with his teleology, but he rejected it; and his great influence, together with the prevailing religious orientation of medieval biology, was sufficient to enthrone teleology and submerge natural selection. It was not until the second half of the 19th century that natural selection became the vogue in scientific circles. The reviewer believes that Agnes Arber's treatment of the *philosophy* of morphology would have been greatly strengthened if the subject had been considered in the light of both natural selection and teleology.

CONWAY ZIRKLE

PLANT PHYSIOLOGY

ANNUAL REVIEW OF PLANT PHYSIOLOGY. *Vol. I. Editor: D. I. Arnon. Annual Reviews, Stanford, Cal.* $6.00. x + 364 pp.; ill. 1950.

This new publication of critical reviews is the latest offspring of *The Annual Review of Biochemistry*. As such, the present volume takes over some of the duties of its parent publication, by including the several important topics of plant biochemistry and physiology hitherto reviewed at regular intervals in *The Annual Reviews of Biochemistry*. More important is the fact that it greatly extends the coverage of the field of plant biochemistry and physiology, thus establishing the first regular major review "journal" in the field as a separate entity. Aside from providing the opportunity for workers in any specialized aspect of plant biochemistry and physiology with a critical posting of progress in other phases of the subject, it will serve the long-needed function of integration and synthesis in the broad field of plant physiology. In the declaration of purpose and scope, the editors state: "The contents of each volume are to be built around a core of annual reviews in areas of great activity, such as inorganic nutrition of plants, photosynthesis, and growth substances. In addition, other reviews are to be included at biennial or longer intervals, depending upon the extent of current research activity and publication." The scope of the new series will also extend to related disciplines, such as plant and soil relationships and physiological anatomy, as well as to the applied fields of horticulture, agronomy, and forestry.

It seems unfortunate that the title of this new publication does not include the term "plant biochemistry." Perhaps a more appropriate name would have been "Annual Review of Plant Biochemistry and Physiology" in keeping with the every-accelerating trend of modern research toward laying down the sorely-needed biochemical foundations of plant physiology. The rapidly increasing, high quality and volume of research in plant physiology along formerly deficient biochemical lines indicates the growing significance of this important and fruitful field. This is reflected in the topics which have been treated in the present volume as well as the proposed subjects for Volume II, which will appear next year. Of the fifteen reviews in Volume I, at least half are concerned in whole or in large part with topics in plant biochemistry. The excellent paper entitled Respiration of Higher Plants (D. R. Goddard and B. J. D. Meeuse) deals with the literature since 1946 and provides an extensive and critical evaluation of the progress made in intermediate metabolism, enzymology, and the association of respiration with growth, salt metabolism, and related topics. The articles Organic Acid Metabolism (K. V. Thimann and W. D. Bonner, Jr.), Transformation of Sugars in Plants (W. Z. Hassid and E. W. Putman), Carbon Dioxide Fixation by Green Plants (A. A. Benson and M. Calvin) and The Nitrogenous Constituents of Plants with Special Reference to Chromatographic Methods (F. C. Steward and J. F. Thompson) further serve to integrate and emphasize the progress which has been made in recent years in these particular aspects. The field of growth has been expanded into five reviews: The Influence of Light on Plant Growth (M. W. Parker and H. H. Borthwick); Plant Tropisms (A. R. Schrank); Growth Regulating Substances in Horticulture (J. W. Mitchell and P. C. Marth); Herbicides (A. G. Norman, C. E. Minarick, and R. L. Weintraub); and Physiology of Cell Wall Growth (A. Frey-Wyssling). Mineral Nutrition in Plants (E. G. Mulder), and Soil Chemistry in Relation to Inorganic Nutrition of Plants (P. R. Stout and R. Overstreet) provide a modern and up-to-date picture of progress in these fields. Water relationships are handled by P. J. Kramer and H. B. Currier in Water Relation of Plant Cells and Tissues, and by F. J. Veilmeyer and A. H. Hendrickson in Soil Moisture in Relation to Plant Growth. The journal is rounded out with the inclusion of J. B. Biale's paper, Post Harvest Physiology and Biochemistry of Fruit.

This publication has made an excellent start, and shows promise of living up to the high standards and reputation of its parent journal. The advantages and need for such a publication are obvious. On the other hand, the point has been raised in several quarters that the break from the *Annual Review of Biochemistry* means less contact of the plant physiologist with the work of the animal scientist and vice versa. Such an objection is minor compared to the wide benefits gained by the establishment of the present journal.

ALVIN NASON

ECONOMIC BOTANY

MELHORAMENTO. *Estudos da Estação de Melhoramento de Plantas. Vol. I, No. 1. 1948. Elvas, Portugal.* Paper.

The articles of this new agronomic journal are in Portuguese, but with English summaries.

PRINCIPLES OF AGRICULTURE. *Second English Printing. By W. R. Williams; translated from the Russian by G. V. Jacks. Hutchinson's Scientific and Technical Publications, London, New York, Melbourne, Sydney, and Cape Town.* 15/- net. 156 pp.; ill. 1949.

This volume affords the only available translation of Williams' important work, in which that noted Russian advocate of ley-farming as a basis for permanent agriculture presented many of his ideas and theories. Williams' book is worthy of more than passing interest on the part of Americans and others outside the Iron Curtain, since the highly publicized 15-Year Plan for

the development of agriculture in the semi-arid areas of the European portion of the Soviet Union applies the author's principles on a vast scale, with apparently an unalterable belief in their infallibility.

The book is an amazing revelation of the way in which a Soviet scientist's mind works, and the manner in which he expounds his science. The presentation is dogmatic, with ever-recurring references to Soviet doctrines. The ideas expressed often appear to be ideological concepts or mere propaganda, rather than statements of facts backed up by experimental evidence. The statistics are frequently meaningless, the generalizations too sweeping, and some of the theories distinctly controversial.

In spite of these shortcomings, however, the book contains much sound information and advocates procedures which are in line with modern agricultural practices elsewhere. These procedures are especially applicable to areas with the same basic problems, such as the great plains of the United States and Canada.

In the opening chapters, the author outlines certain general principles of soil cultivation essential to the maintenance of a satisfactory soil structure, a feature of paramount importance. Such a soil must have a crumb structure throughout its arable horizon, and its fertility must be constantly renewed. Perennial grasses are of the greatest value for this purpose. The next portion of the book outlines a basic plan for land use, with forests on the watersheds, arable land on the slopes, and meadows in the valleys. The author dismisses the grain-fallow system of agriculture as useless, and advocates a "grass-arable" or grass-grain rotation with leys of perennial grasses of a two-year maximum duration alternating with cereals, potatoes, or sugar beets. In the case of meadows, the grass stages should be maintained for 7 or 8 years, with fodder and fiber crops in the rotation. Various special problems, such as spring and autumnal cultivation of the soil, methods and depth of plowing and harrowing, and the use of organic and mineral fertilizers are also discussed.

A perusal of *Principles of Agriculture* leaves the impression that the author firmly believes that if *correct* methods of cultivation are followed, if the fertility of the soil is maintained with proper systems of manuring, etc., if selected seed is used, and if irrigation and erosion control are practiced, then any soil can be *made* to produce with maximum efficiency. The only limiting factor, therefore, to full agricultural productivity is the farmer, not the soil. To overcome this obstacle, the substitution of collectivism for individual initiative is essential. Few, if any, agriculturists outside the U.S.S.R. will agree with the latter thesis, even though they may approve of many of the agricultural practices advocated.

ALBERT F. HILL

THE PROPAGATION OF PLANTS. *Second Impression. By E. J. King. Hutchinson's Scientific and Technical Publications, London, New York, Melbourne, Sydney, and Cape Town.* 16s net. 264 pp.; ill. No date.

This is a readable and intelligently handled book covering the many phases of propagation encountered in horticultural work. Although written as a textbook for English students of horticulture, its usefulness is by no means so narrowly limited.

VEGETABLE CROPS. *Fourth Edition, second impression. By Homer C. Thompson. McGraw-Hill Book Co., New York, Toronto, and London.* $6.00. viii + 611 pp.; ill. 1949.

The previous editions of *Vegetable Crops* firmly established this work as the most scientific in its field. In discussing the production and handling of vegetables, the author stresses the application of facts and principles based on experimental evidence, rather than directions for performing the various operations. The Fourth Edition maintains the same high standards, and incorporates the results of the large amount of research carried on since 1940, the original references to which may be found in the extensive bibliography. Many subjects have been extensively revised and several new ones added, particularly in connection with the nutritional value of vegetables, plant nutrition, fertilizers, weed control, and methods of preparation for market. The chapter on the classification of vegetables has quite properly been moved to the beginning of the book. An entire chapter is now devoted to the potato and another to the sweet potato. The general method of treatment, however, remains the same. The presentation throughout is such that, although the material is technical, it can be assimilated as readily by the layman as by the college student.

ALBERT F. HILL

THE GRAPE VINE IN ENGLAND. *The History and Practice of the Cultivation of Vines in England; an Account of their Origin and Introduction; a Guide to the Plantation and Care of Vineyards To-Day; a Refutation of the Notion that English Weather is Hostile to the Vine; a Description of the Way to Make Wine. By Edward Hyams; introduction by V. Sackville-West. The Bodley Head, London.* 16s net. 208 pp. + 12 plates; text ill. 1949.

Essentially a plea for the return of viticulture and wine making to England, this book contains an excellent history of the subject, as well as a thorough discussion of the cultural practices which have been found to be successful. The author writes well and with humor,

and Sackville-West has contributed a delightful preface. The book should assist materially in the amelioration of the effects of England's present austerity.

C. P. SWANSON

LA SISTEMATICA DEL LINO. *Secondo Wulff Ed Elladi. By Raffaele Ciferri. Centro di Studi per le Ricerche sulla Lavorazione Coltivazione Ed Economia della Canapa, Facoltà Agraria della R. Università degli Studi di Bologna.* L. 1000. 203 pp.; ill. 1949.

This is essentially a translation of the very detailed account of the cultivated races of flax written by E. V. Wulff and K. V. Elladi and published in 1940 in Volume 5 of Vavilov & Wulff's *Flora of Cultivated Plants*, a publication of the Lenin Academy of Agricultural Science. Ciferri's book departs from the Russian text in a few details. In a chapter giving statistics concerning flax-growing and flax-production over the world, elaborate statistics for the U.S.S.R. given by Wulff are cut down, while figures for Italy are given in correspondingly greater detail. Ciferri adds about 7 named races (all from Abyssinia) to the more than 150 previously named and characterized by Elladi. Some recent titles, chiefly Italian, are also added to the bibliography.

Translated into Italian, with some additions and only minor changes and omissions, the work of Wulff and Elladi is now presented in a language much less formidable than Russian. Furthermore, it again makes available the monograph of the talented Russian botanist, the Russian text being now extremely difficult to acquire. For these interested in flax, Ciferri's translation should be most welcome.

IVAN M. JOHNSTON

GENERAL AND SYSTEMATIC ZOOLOGY

TAXONOMIC KEYS. *To the common animals of the North Central States exclusive of the Parasitic Worms, Insects and Birds.*

By Samuel Eddy and A. C. Hodson. Burgess Publishing Co., Minneapolis, Minnesota. $2.00. iii + 123 pp.; ill. 1950.

Unless one has the good fortune to be acquainted with Archie Carr's *Key to the Fishes of Alachua County*, tables for the identification of animals or plants in the form of dichotomous (and only too often trichotomous) "Keys" must appear to be one of the most refractory of literary forms. The verbless couplets deal with those characters that some of my colleagues refer to as "useful," meaning useful to themselves, not to the animals; and these characters range over the whole external anatomy of the animals to be identified. To theoretical taxonomy, the meaning of the characters that distinguish animals, whether or not useful in any sense, is of the utmost importance, and an understanding of the significance of such characters will require a resurvey of most of the animal kingdom. For the practical business in hand, that of directing the attention of elementary students to external features that make possible the identification of *specimens* with known genera and species, such questions need not be raised at all.

Eddy and Hodson have evidently produced a useful key, relatively well illustrated and relatively up to date, arranged perhaps somewhat too specifically for the needs of a particular class. All such means of identification improve with use and revision. It is perhaps therefore proper for a friendly critic to suggest additions and changes that seem desirable to him. The technique of illustrating the couplets of the key by means of figures of the alternative characters, rather than by referring the user to a figure on another page, seems to have proved its usefulness. Eddy and Surber have employed habitus figures of animals assembled on whole pages, though with the excellent feature of illustrated glossaries, which, for some reason are wanting for amphibians, reptiles, and mammals. References should have been given for the groups of animals omitted from the keys. The most readable single work on North American mammals, Seton's *Lives of Game Animals*, is not listed. The handbook for German students that most closely corresponds to the Eddy and Hodson Keys, Brohmer's *Fauna von Deutschland* (6th edition, 1949), is of interest for comparison with an American work. Its inclusiveness seems commendable. For limited purposes keys may consist mainly of illustration, like those prepared under the direction of H. R. Dodge, of the Public Health Service, for the identification of the Diptera of importance to public health. This form represents the extreme of simplification and usability, and deserves scrutiny by all makers of keys.

KARL P. SCHMIDT

OBSERVATIONS ON FLAGELLUM STRUCTURE IN FLAGELLATA. *Univ. Cal. Publ. in Zool., Vol. 53, No. 11.*

By Dorothy R. Pitelka. University of California Press, Berkeley and Los Angeles. $1.25. Pp. 377–430; ill. 1949.

NOTES ON ASTEROIDS IN THE BRITISH MUSEUM (NATURAL HISTORY). LERNAEODISCUS PUSILLUS NOV. SPEC., A RHIZOCEPHALAN PARASITE OF A PORCELLANA FROM EGYPT. *Bull. Brit. Mus. (Nat. Hist.), Zoology, Vol. I, No 4.*

I. By D. Dilwyn John. II. By Hilbrand Boschma. British Museum (Natural History), London. 4s. (paper). Pp. 51–65 + 1 plate; text ill. 1950.

A STUDY OF PALAEOZOIC ARACHNIDA. *Trans. Conn. Acad. Arts & Sciences, Vol. 37.*

By Alexander Petrunkevitch. Connecticut Academy of Arts and Science, New Haven; Yale University Press, New Haven. $7.70 (paper). Pp. 69–315 + 83 plates + xi pp. 1949.

Almost all the recent work on the fossil arachnids has been done by Alexander Petrunkevitch who, in his fruitful studies of this difficult record, has developed special techniques for its preparation and analysis. In the present monograph, based largely on the collections of the British Museum, he gives a comprehensive summary of our present knowledge of the paleozoic fauna. A great many corrections and new interpretations have resulted from this modern restudy of the classic material of former students.

The earliest fossil records of the Arachnida are Silurian scorpions, represented by only 4 specimens comprising three European and one North American species (*Palaeophonus* (= *Proscorpio*) *osborni* Whitfield). After a consideration of all the available evidence, Petrunkevitch subscribes to the belief, first expressed by Thorell and Lindström, that these primitive scorpions are normal, air-breathing types, and are not the aquatic or semiaquatic creatures of popular fancy. The pointed tarsi and the persistence of the tergite of the first abdominal somite distinguish these proscorpiones from those that followed.

Three orders of the Arachnida, the Acari, the Araneae, and the Trigonotarbi, are known from the Devonian of Scotland, and all sixteen orders (one of these the new order Trigonotarbi proposed for arachnids previously considered to be Anthracomarti) were in existence at least in the late Paleozoic. Five orders died out in the Paleozoic.

The class is divided into four subclasses based on differences in juncture of the cephalothorax and the abdomen. The new subclass Soluta comprises the order Trigonotarbi in which the juncture is variable, being either of the broad type or resembling the petiolated type. In the new subclass Stethostomata, comprising the Haptopoda and Anthracomarti, the juncture is broad and the first embryonic abdominal somite is fully retained, not virtually obsolete. The subclasses Latigastra and Caulogastra are redefined.

This is a very important contribution in which numerous new discoveries are recorded and engaging discussions of new relationships and evolutionary trends are given.

W. J. GERTSCH

PHALANGIDA FROM TROPICAL AMERICA. *Fieldiana: Zoology, Vol. 32, No. 1.*

By Clarence J. and Marie L. Goodnight. Chicago Natural History Museum, Chicago. 75 cents (paper). 58 pp.; ill. 1947.

This work is strictly taxonomic and is based upon the collecting of numerous workers in several countries. There are detailed descriptions of nearly 50 species, of which 28 are new to science. Various families are represented, and it was found necessary for the authors to erect 7 new genera.

B. J. KASTON

THE PSEUDOSCORPIONS OF ILLINOIS. *Bull. Ill. nat. Hist. Surv., Vol. 24, Art. 4.*

By C. Clayton Hoff. Department of Registration and Education, Natural History Survey Division, Urbana, Illinois. 50 cents (paper). vi + pp. 413–498; ill. 1949.

In the preliminary portion of this monograph considerable attention is given to the general biology and habits of these animals, to collection methods, and to general morphology. The systematic part is well arranged with keys to suborders, and to all lower categories. The descriptions are quite detailed for the most part, and are accompanied by drawings illustrating important characters. In addition to the description, the author has supplied for each species some comments concerning relationships with other species, distribution notes, Illinois locality records, and ecological data.

Since the keys were made to include all the genera known from the central and northeastern portions of the United States, and since there has been no detailed faunistic publication on pseudoscorpions for any region in North America, Hoff's monograph is a valuable contribution that will make the task of later workers immeasurably easier.

B. J. KASTON

INTRODUCING THE INSECT.

By F. A. Urquhart; drawings by E. V. S. Logier. Henry Holt & Co., New York. $5.00. x + 287 pp.; ill. 1949.

The average book for the beginning student of insect identification is not particularly interesting to read. *Introducing the Insect*, however, is an exception, and in its pages one may find many evenings of reading enjoyment. The book is intended as an introduction to the subject of entomology, but is more adapted to the layman than to the serious student. Specialized terminology has been omitted; this is an obvious advantage to laymen with only a casual interest, but on the other hand is a serious drawback for students who intend to probe the subject more deeply. Only a limited number of common insect families have been considered, and hence the keys cannot be used for insects which have been omitted—and how can the beginner know that *his* insect has been omitted?. The keys have also been written with the expressed intention of using "easy"

characters applicable to the majority of species in a group, a method which will lead to misidentification or frustration if one of the minority is encountered. This practice may be justified in an elementary work of this sort, though the reviewer is dubious that the good intentions of the author will be realized. The illustrations are superbly hand-drawn and are very clear. For the butterflies and moths two color plates are included.

The common insects introduced in this book are those found in the northeastern part of the United States and adjacent Canada. Outside this area, the value of the book for identification purposes diminishes, owing to the fact that the plan of the keys is based upon the relative abundance of species in a geographical area. The text appears to be scientifically sound and conservative. The book may therefore be recommended to high school biologists, or to the layman, with no fear of misleading statements. The publishers, the author, and the artist have combined to put out a work which is excellent for the purpose intended.

WILLIAM HOVANITZ

REVISION OF THE NORTH AMERICAN SPECIES OF THE GENUS EUPITHECIA (LEPIDOPTERA, GEOMETRIDAE). *Bull. Amer. Mus. nat. Hist., Vol. 93: Art. 8.*

By James H. Mcdunnough. American Museum of Natural History, New York. $2.50 (paper). Pp. 533–728 + 7 plates; text ill. 1949.

A REVISION OF THE GEOMETRID MOTHS FORMERLY ASSIGNED TO DREPANULATRIX (LEPIDOPTERA). *Bull. Amer. Mus. nat. Hist., Vol. 94, Art. 5.*

By Frederick H. Rindge. The American Museum of Natural History, New York. 75 cents (paper). Pp. 231–298; ill. 1949.

These are systematic studies of the moth groups indicated based upon comparative morphology. The first paper gives a detailed structural study of the genus *Eupithecia*, and this is followed by descriptions of each species. Differentiating characters are based primarily upon the male and female genitalia. There is no general section included that might indicate evolutionary progress in the group or comparative geographical distributions. The style is authoritative. The reader has little opportunity to determine either the extent of the material available to the author and from which he draws his conclusions as to relationships in the genus, or the natural variability in the material studied. The revision is antiquated in style.

Rindge's shorter revision of *Drepanulatrix* is improved by full-page maps of the geographical distributions of the species, and by the addition of biological data such as larval breeding experiments, in addition to the usual comparative morphology. A table indicates the flight periods of the adult moths during the year, and another, the duration of life of three species during the various developmental stages. The latter has little significance, inasmuch as no controls over environmental conditions were made.

WILLIAM HOVANITZ

MOSQUITOES OF THE GENUS TRIPTEROIDES IN THE SOLOMON ISLANDS. *No. 3262—From the Proc. U. S. nat'l. Mus., Vol. 100.*

By John N. Belkin. Smithsonian Institution, United States National Museum, Washington, D. C. Pp. 201–274; ill. 1950.

This first in a series of monographs on the culicines of the Solomon Islands adds 7 new species to the 2 already described in the genus.

THE LUNGFISH, THE DODO, AND THE UNICORN. *An Excursion Into Romantic Zoology. Third Edition.*

By Willy Ley. Viking Press, New York. $3.75. xiv + 361 pp.; ill. 1948.

The author's amusing Preface to the Revised Edition (vide *Q.R.B.*, 16: 490. 1941) likens his book to the African lung-fish, which comes out of a prolonged estivation with no visible emaciation. The book, in fact, has actually gained in weight—and its friends and readers, of whom it is hoped there will continue to be many, may indeed be glad of this. The earlier stories of the zoological myths such as the unicorn, the basilisk, or the kraken, were engrossing, and Ley's detective work in tracing the clues until he arrived at sure, or at least at plausible, derivations of the myths was fine indeed. Part Two, on such extinct creatures as the usus, wisent, great auk, dodo, and giant sloth, no one would skip. Yet to a biologist the richest store of interesting information surely lies in the well-told stories of Part Three: Limulus and Latimeria; A Century of Platypus; The Lungfish that Made History; New Zealand Interlude; Two-Thumbed Teddybear; The Origin of the Mammal; and African Rhapsody. For here is the story of the discoveries of various "missing links" and the exciting impact of such finds on zoologists eager for evidence bearing upon the Theory of Evolution. Here *Sphenodon* shares honors with *Neoceratodus*, the okapi, and many others. One can only wish there were more. Perhaps Willy Ley will write us another book with equally fascinating characters—Amphioxus, for example. It will be with impatience that we must wait.

BENTLEY GLASS

AUSTRALIAN JOURNAL OF MARINE AND FRESHWATER RESEARCH. *Vol. 1, No. 1.*

Commonwealth Scientific and Industrial Research Or-

ganization, East Melbourne, Victoria, Australia. Issued as material becomes available. 30s. per annum; 7/6 per issue (paper). Vol. 1, no. 1: 154 pp. + 12 plates; text ill. April, 1950.

This new journal is uniform in format with the *Australian Journal of Scientific Research, Series B* and the *Australian Journal of Agricultural Research*. The first issue contained the following papers: A Biological Study of the Anchovy, *Engraulis australis* (White), in Australian Waters (M. Blackburn); Investigations on Underwater Fouling. I. The Role of Bacteria in the Early Stages of Fouling (E. J. Ferguson Wood); Investigations on Underwater Fouling. II. The Biology of Fouling in Australia (F. E. Allen & E. J. Ferguson Wood); Investigations on Underwater Fouling. III. Note on the Fouling Organisms Attached to Naval Mines in North Queensland Waters (F. E. Allen); The Condition of the Fishery for Barracouta, *Thyrsites atun* (Euphrasen), in Australian Waters (M. Blackburn); The Bacteriology of Shark Spoilage (E. J. Ferguson Wood); The Effects of the Orientation of Cultch Material on the Setting of the Sydney Rock Oyster (J. M. Thomson). The half-tone plates are of excellent quality.

Number 2 appeared in December, 1950.

THE FAMILIES AND GENERA OF LIVING RODENTS. *Brit. Mus. (Nat. Hist.). Vol. III, Part I.*

By J. R. Ellerman; with a list of named forms by R. W. Hayman and G. W. C. Holt. British Museum (Natural History), London. 1s. 10d. vi + 210 pp. 1949.

Living rodents are probably more abundant in numbers of individuals and in variety than all other mammals put together. There are somewhere near 6500 named forms comprised in 338 genera and 32 families. They inhabit all major land masses of the world and occur in almost every conceivable environment. Their phyletic connections are exceedingly difficult to trace amidst the confusing network of convergence, divergence, and parallelism that is abundantly evident in the order Rodentia.

Sir John R. Ellerman has performed the monumental task of assessing the systematic status of all named genera of the Rodentia as a means of arriving at a key for identification and a classification of rodents. In his three-volume monograph he presents a personal view of this large and complex group of mammals. Volume I is concerned with rodents other than those of the family Muridae. Volume II covers the Muridae. Those two volumes were issued in 1940 and 1941, respectively. Part II of Volume III is to be an illustrative atlas, containing chiefly figures of important morphological features of rodents, and has not yet been published, to my knowledge. Part I of Volume III consists entirely of notes on various genera and on various publications that have come to Ellerman's attention since the preceding volumes went to press. The first 115 pages contain additions and corrections to Volumes I and II. The notes on some genera are full. Those on the genus *Rattus*, for example, essentially amount to a revision of the genus. There follows an appendix of 39 pages which contains observations on Simpson's *Principles of Classification* (*Bull. Amer. Mus. nat. Hist.*, 85: 1945). A final section of Part I, headed Addenda, consists of further remarks on a few genera. This section warrants especial note. A chief criticism that has been levied against Ellerman's excellent work is that it is a classification of characters, not of animals (Simpson, 1945: p. 199). It seems apparent in these volumes that he has lacked a phylogenetic or historical point of view in his approach to his subject. In the last section of the present publication I get the impression that Ellerman's viewpoint in systematics may be in course of becoming a modern one. His three-volume monograph is of tremendous value to all who are interested in that large and complex order, the Rodentia. It is an absolute necessity for students of mammalian systematics.

E. T. HOOPER

ECONOMIC ZOOLOGY

PRINCIPLES AND METHODS OF ANIMAL BREEDING. *Second Edition.*

By R. B. Kelley. John Wiley & Sons, New York. $3.50. x + 383 pp.; ill. 1949.

The story of animal breeding from Bakewell to the modern development of population genetics is told in a simple, interesting but generally non-critical way. Adequate attention is given to environmental variation and adaptation. The book contains a brief history of the Shorthorn, Aberdeen-Angus, and Hereford breeds of beef cattle. There are three chapters on animal breeding in Australia. Appendix I describes Wright's coefficients of inbreeding and relationship. Appendix II is a glossary of terms.

Readers with a general interest in animal breeding, nonprofessional students, farmers and ranchers, as well as professional students and research workers, will enjoy learning from Kelley's rambling text.

T. C. BYERLY

PRACTICAL ANIMAL HUSBANDRY.

By Jack Widmer, with drawings by Eleanora B. Black and photographs by Edward A. Lane and Jack Widmer. Charles Scribner's Sons, New York and London. $3.50. xvi + 159 pp.; ill. 1949.

Here is a pleasant primer of subsistence livestock production. It is generally well written and nicely

illustrated. Information on the production of beef, sheep, hogs, rabbits, chickens, turkeys, ducks, geese, pigeons, and guinea fowl sufficient for family food requirements is adequate and understandable. There is a short section on meat curing and preservation.

The author, while technically correct in his statement (p. 148) that goats do not have Bang's disease, surely should have added that they may be hosts to *Brucella melitensis*, more virulent for man than the Bang's organism, *Br. abortus*. Small oversights, e.g., "hempstead" instead of "hempseed" (p. 108) and "species" instead of "variety" (p. 111), are not infrequent.

City dwellers dreaming of abundant living on the farm will derive pleasure and instruction from the book. Country folk will enjoy it, too.

T. C. Byerly

Garden Ponds, Fish and Fountains. *Revised Edition.*

By A. Laurence Wells. Frederick Warne & Co., London and New York. $1.25. 157 pp. + 4 plates; text. ill. 1949.

Anyone who is interested in building and maintaining any kind of pool in his garden should find this little book useful. It offers suggestions for planning, building, stocking, and maintaining garden ponds. It also discusses fountains, water falls, indoor aquaria, bog and tub gardens, and fish breeding. The book has special value for the beginner but should also help those who have their ponds already established.

Ella Thea Smith

ANIMAL GROWTH AND DEVELOPMENT

Problems of Morphogenesis in Ciliates. *The Kinetosomes in Development, Reproduction and Evolution.*

By André Lwoff. John Wiley & Sons, New York; Chapman & Hall, London. $2.50. x + 103 pp.; ill. 1950.

This small volume is a presentation of descriptive data on the cytoplasmic differentiation of certain apostomatous ciliate protozoa, with an attempt to relate these specialized findings to general problems of morphogenesis. A careful study is presented of the microscopic anatomy and its changes during the life cycle in several species, principally of the Apostomae, which Lwoff and his colleagues have made their special province. The larger significance which is seen in this material is that the genetic continuity of the cytoplasmic structures of ciliates constitutes a striking though long neglected case of visible and indisputable cytoplasmic inheritance.

In these and other ciliates we find rows and networks of cilia, cirri, trichocysts, etc., present in definite number and pattern. Each organelle is associated with and derived from a granule in the ectoplasm which is either self-reproducing or derived from self-reproducing granules. The granules in turn are joined together by fibers. This underlying pattern of fibers and granules undergoes transformations and increases without loss of genetic constitution during metamorphoses and cell divisions. Hence in these organisms "cytoplasmic inheritance" is not incidental but constitutes almost the whole story of differentiation and morphogenesis. The intriguing possibility exists that in the ciliates we may have in the pattern of visible basic fibers and granules an expression of something like an invisible "cytoarchitecture"—an active, spatially organized system in the cytoplasm—which has been hypothesized to explain order in metazoan morphogenesis.

If this proposition is to prove fruitful, an investigation of what is visible in the cytoplasm of ciliates must lead to principles which have new explanatory values when applied to the postulated invisible cytoarchitecture in other forms. On this score the author offers us little help. He attributes morphogenetic determination at one time to the granules, at another to the fibers, and again to an invisible, postulated organization in the (internal) "environment" as well. The possibility that all three of these factors can be operative together is granted, but this compromise will not erect a satisfactory causal chain. It is clear that he favors the priority of the granules, both because of their attractiveness as self-reproducing particles and because they appear to fit into Paul Weiss' scheme of "molecular ecology." Klein, however, has viewed the fibers as primary determinants, since he found them to be in certain instances antecedent to the appearance of the granules associated with and apparently derived from them.

What we now require is experimental interference with the basic, visible cytoplasmic structures of fibers and granules in ciliates so as to reveal, if there be such, new processes and principles of organized cytoplasmic activity that, when projected into the realm of yet invisible cytoarchitecture, will prove fruitful in explaining morphogenetic phenomena in other, even multicellular, organisms.

Vance Tartar

Studies in Experimental Zoology. *Regeneration, Experimental Embryology, Endocrinology. Third Edition.*

By A. Elizabeth Adams. Edwards Brothers, Ann Arbor, Mich. $2.00 (paper). xiv + 120 pp.; ill. 1949.

This is a third edition of a manual of already proved

usefulness and excellence, and improves on its two predecessors principally in the enlargement of its bibliographies and in its addition of some material to the text. This laboratory manual has been in all its editions a model of what the teaching manual should be: concise, accurate, intelligent, and unpretentious. Owners of the previous editions will wish to have the present version for the sake of the new material, and the book is urgently recommended to new users who teach laboratory work involving experimental studies of regeneration, embryology, and endocrinology.

JANE OPPENHEIMER

A STUDY ON GROWTH HORMONE OF ANTERIOR PITUITARY LOBE. *With Special Reference to Determination of Its Biological Potency. Opera Ex Domo Biologiae Hereditariae Humanae Universitatis Hafniensis, Volume 14.*

By P. Fønss-Bech. Ejnar Munksgaard, Copenhagen. Kr. 12.00 (paper). 156 pp. + 3 plates; text ill. 1947.

In fairness to a competent investigator it should be realized that this review appears five years after the completion of his investigations in a very active field. In 1942, when the study was started, growth hormone potency was assayed by three different procedures—weight gain of adult female rats, or of hypophysectomized rats, or tail lengthening of hypophysectomized rats. The author compared these methods, hoping to develop a reference standard. Dissatisfied, he devised a new procedure, based on the pituitary deficiency of hereditary dwarf mice and the reestablishment of growth by the growth hormone. He found this technique superior, and on it based a unit of potency of the hormone. In 1944, however, the "tibia line test" method was described elsewhere. Its omission from Fønss-Bech's comparative studies is unfortunate, since it has become the method of choice of many workers. Another limitation in these studies lies in the hormone used which, though remarkably good for the time, contained traces of thyrotrophin. This hormone almost certainly augments the action of growth hormone. Growth hormone has since been prepared free from other pituitary factors, and the entire question which the author sought to resolve is still open. To the investigator who undertakes the comparison of these or of any other group of bioassay methods, Fønss-Bech's dissertation will serve as a model. For those with more general interest in the subject, there is an excellent review of the biological and chemical properties of the hormone, and a full bibliography, both terminating with the status in 1945.

C. WILLET ASLING

LE SEXE. *Rôle de l'Hérédité et des Hormones dans sa Réalisation. La Science Vivante.*

By Vera Dantchakoff. Presses Universitaires de France, Paris. 480 fr. (paper). 210 pp.; ill. 1949.

In the course of the past 25 years, Mme. Dantchakoff has been the author of nearly 50 articles dealing with the role of the sex hormones in embryonic sex differentiation. It was anticipated that the present volume might contain a synthesis of the recent advances in the field of sex differentiation, woven about a discussion of the author's own investigations. It is regrettable that this goal has not been realized. As indicated in the subtitle, *Le Sexe* is concerned with both the genetic basis of sex determination and the role of hormones in sex differentiation. Neither topic has been discussed adequately. The sections of the book dealing with sex determination are, on the whole, factually correct, although tedious and uninspired. On the other hand, the sections dealing with sex differentiation (particularly Chapters I, VI, and VII) are not only dull, but contain numerous errors. Neither data nor sources are presented in support of many of the statements made, and several of the author's conclusions seem unwarranted. Throughout this portion of the book there is often no distinction between assumption and fact. Moreover, much of the comparatively recent work having an important bearing on the subject has been ignored. These omissions are especially noticeable in the discussion of sex differentiation in mammals. Little or no attention has been paid, for example, to the work of R. K. Burns and C. Moore on the opossum, or to the several recent studies by A. Jost. In short, this book offers nothing to the specialist in the field and little, if anything, to the student of biology.

JAMES D. EBERT

ANIMAL MORPHOLOGY

PRACTICAL INVERTEBRATE ANATOMY.

By W. S. Bullough. Macmillan & Co., London. $4.50. xii + 463 pp.; ill. 1950.

This laboratory guide for the study of the invertebrates and lower chordates has many admirable features. The type is large and clear, the taxonomic status of each type is conspicuously presented, the main structural features of each animal are illustrated in neat drawings with labels printed out in full, and directions for the culture, fixation, and staining are given for many of the materials employed. On the other hand, many of the descriptions, especially of the larger forms, are cursory and may leave the student unsatisfied, and the text and figures contain a large number of factual errors. A few examples of these may be mentioned: the trichocysts of *Paramecium* are

said to be sacs of fluid that forms a thread when discharged through a pore; *Paramecium* is said to have myonemes; oral groove and cytopharynx are confused and the ciliation of the cytopharynx is ascribed to the oral groove; hydras are said to be protandric hermaphrodites, whereas most of them are dioecious; the white planarian *Procotyla* is considered identical with *Dendrocoelum* and the textual account and figures confuse features of these two distinct genera; similarly, the polyclad *Hoploplana inquilina* found in the branchial chamber of *Busycon* is called by the original erroneous name of *Planocera* and the text and figures then proceed to attribute features of *Planocera* to *Hoploplana*; the free-living nematodes are classified as Ascaroidea; the genital papillae of rhabditoid nematodes are called bursal rays; and everywhere cuticularized structures are referred to as "chitinous."

L. H. HYMAN

TEXTBOOK OF ANATOMY AND PHYSIOLOGY. *Third Edition.*

By Catherine Parker Anthony. C. V. Mosby Co., St. Louis. $4.00. 614 pp.; ill.; 5 plates. 1950.

The third edition is essentially the same as the previous ones, although it contains considerably more physiology. The text is well written in a concise, clear style and is very well indexed, and to it is added an adequate bibliography. It can be recommended for students of nursing.

DAVID B. TYLER

TEXTBOOK OF ANATOMY AND PHYSIOLOGY. *Second Edition.*

By Carl C. Francis and G. Clinton Knowlton. C. V. Mosby Company, St. Louis. $6.25. 624 pp. + 31 plates; text ill. 1950.

This second edition has been rather extensively revised to include many new illustrations and to allow a rearrangement of material so as better to integrate the anatomy and the physiology. It is adequately indexed and well illustrated with many original drawings and color plates. It can be recommended for student nurses, as well as for elementary courses at the collegiate level.

DAVID B. TYLER

ATLAS OF HUMAN ANATOMY—*Descriptive and Regional. Volume II (Splanchnology, Angiology, Nervous System, Organs of Sense).*

By M. W. Woerdeman. Blakiston Co., Philadelphia and Toronto. $10.00. 642 plates; index. 1950.

This volume follows the pattern of the first one, which dealt with osteology, arthrology, and myology (see *Q. R. B.*, 24: 370. 1949). It maintains the same high standards of illustration and printing. Certainly this is one of the best atlases of human anatomy now available.

W. L. STRAUS, JR.

BUCHANAN'S MANUAL OF ANATOMY. *Eighth Edition. Edited by F. Wood Jones. Williams & Wilkins Co., Baltimore (printed in Great Britain).* $8.50. xviii + 1616 pp. + 48 plates; text ill. 1950.

Buchanan's old and reliable textbook of human gross anatomy, well-known in Great Britain, was very thoroughly revised for its seventh edition in 1946 (*Q. R. B.*, 23: 256. 1948). This latest edition contains precisely the same number of pages and of illustrations as the preceding issue, though the paper is somewhat heavier and, hence, the volume is half an inch thicker. In spite of a prolonged, careful comparison between the 7th and 8th editions, the reviewer has been unable to detect the slightest difference in the contents of the two!

As a mere description of the construction of the average adult body of white man, this textbook is equal to most of the great many other Human Anatomies. The chapter on osteology, which forms nearly one-fifth of the volume, gains much in interest through its consideration of development and variability, in contrast to the other, somewhat dogmatic sections, which emphasize average topographical conditions. With the exception of the good roentgenological plates, most of the figures are so diagrammatic—even crude—that they can no longer compete with the illustrations of some other, modern textbooks. The moderate price of this book is its main advantage, though the less bulky seventh edition seems preferable.

A. H. SCHULTZ

ANATOMY FOR DENTAL STUDENTS.

By Mary F. Lucas Keene and J. Whillis. Edward Arnold & Co., London. American Distributor: Williams & Wilkins Co., Baltimore. $7.50. viii + 342 pp.; ill. 1950.

This book carries out with exceptional merit the objective stated in its preface: "the selection of the anatomical facts needed by a student in Dentistry." The illustrations are almost all original, and superior in quality. Many American anatomists reject the initial proposition that "the traditional method, although suitable in training medical practitioners is not so satisfactory for dentists." No mention is made of the laboratory or demonstration work which must accom-

pany the use of any textbook in anatomy. There is an adequate index but no bibliography. The reviewer believes that this book will be found most valuable in American dental colleges when used as a handbook by students who have completed the course in basic anatomy, or as a textbook in second courses offered to upper class students.

JOHN A. CAMERON

EXPERIMENTAL SURGERY, *Including Surgical Physiology. Second Edition.*

By J. Markowitz. Williams & Wilkins Company, Baltimore. $7.00. xiv + 546 pp.; ill. 1949.

Like the first edition, this is a clearly-written, authoritative work. The emphasis is again on surgery of the digestive system, and most of the specific operative techniques described are still based on work with the dog. As before, the book serves as an excellent introduction to practical surgery for medical students, but it is also invaluable as a handbook of surgical techniques for the research worker.

Six chapters in the beginning of the book are devoted to basic considerations in experimental surgery, such as care of animals, anesthesia, asepsis, surgical instruments, suturing techniques, and basic procedures like opening and closing the abdomen and thorax. As one might expect, these chapters are changed little from the first edition.

In nine chapters, a variety of techniques useful in surgery of the alimentary canal are described in detail: gastric and intestinal fistulae, gastric pouches, exteriorization of an intestinal loop, esophageal surgery, and surgery in peptic ulcer and in peritonitis. These are but a few of the many techniques discussed, and in many cases, more than one surgical approach is described.

The remaining chapters take up surgical techniques in work on the pancreas, gall bladder, and liver, intracranial surgery (including hypophysectomy and decerebration), and surgery of the autonomic nervous system, the heart, and the vascular system.

A fair amount of the material discussed in these chapters and many of the figures are taken almost directly from the first edition. But descriptions of many new surgical techniques have been added, and the second edition offers much more discussion of surgical physiology than the first.

ELIOT STELLAR

A TEXT-BOOK OF NEURO-ANATOMY. *Fifth Edition, thoroughly revised.*

By Albert Kuntz. Lea & Febiger, Philadelphia. $8.00. 524 pp.; ill. 1950.

No extensive review seems needed of this well-known textbook. The main changes from the preceding edition are those required to bring the anatomical descriptions up-to-date. There has been some rearrangement of the text, and a new chapter has been added on conditioned reflexes. The useful practice of placing a summary and bibliography at the end of each chapter has been retained.

MARTIN G. LARRABEE

GYNAECOLOGICAL AND OBSTETRICAL ANATOMY. *Second Edition.*

By C. F. V. Smout; with chapters on The Histology of the Female Reproductive Tract and its Endocrine Control by F. Jacoby. Edward Arnold & Co., London (American Distributor: Williams & Wilkins Co., Baltimore). $11.00. xii + 248 pp. + 33 plates; text ill. 1948.

This is a remarkable book, in parts really superb. It is the answer to the prayer of the postgraduate who is studying for his specialty examinations in gynecology and obstetrics, and it is equally valuable to the established clinician who wants to review the basic anatomy of this branch of medicine. The authors are primarily anatomists, one attached to the anatomy department of the University of Birmingham, the other to the University of Cardiff.

The first 40 pages dissect the bony pelvis: its morphology, axes, mensuration, diameters, pathology, and the classification of pelvic types. The latter is based on the work of the Americans Caldwell and Moloy, and Thoms. In succeeding chapters the ligaments, joints, muscles, and connective tissues of the pelvis are discussed. The embryology and anatomy of the ovaries and uterus occupy the next 100 pages. The pelvic portions of the genito-urinary and alimentary tracts receive the same detailed treatment. The 2 final chapters discuss the placenta and the anatomy of the fetus in relation to childbirth.

The book is very uneven. When the authors stick to ungarnished anatomy the result is splendid, but when they become lured into a discussion of extrinsics the account becomes quite commonplace. The 10 pages devoted to the ligaments of the uterus are outstanding in clarity, emphasis, and detail; not so the contributions on the placenta and fetus. For example, there are 2 errors in one brief paragraph which discusses the placenta in twin pregnancy. The authors state that in binovular twinning "the placentae usually remain entirely separate," while actually they are fused in 55 per cent of cases. They omit completely the 10 per cent of single egg pregnancies in which there are 2 placentas, from those cases in which division occurs in the early morula stage. In discussing the fetus they write that "children weighing under 5 lbs. die shortly after birth more often than not." This is only true for chlidren weighing less

than 3½ lbs., many more being reared than lost in the weight group between 3½ and 5 lbs.

The style is to be envied by us Americans, the book being written with the good British flourish. The scientist authors even indulge in teleological philosophy. In discussing the growth of the round ligaments during pregnancy, they are sure it must be purposeful, even though that purpose is yet unrevealed. To the reviewer it seems more plausible to say that the estrogenic hormone which causes the smooth muscle of the uterus to hypertrophy during pregnancy similarly affects the smooth muscle of its main ligaments, since they are part of the uterus and also largely made up of smooth muscle. It is just as logical to say that the partial inhibition of peristalsis in the ureters and gut during pregnancy which leads to urinary stasis and constipation is purposeful, rather than a byproduct of hormonal sedative influences on the smooth muscle of the uterus.

The book is well printed and very excellently and copiously illustrated. I advise all interested in gynecology and obstetrics to add it to their libraries.

ALAN F. GUTTMACHER

HISTOLOGY.

By Arthur Worth Ham. J. B. Lippincott Co., Philadelphia, London, and Montreal. $10.00. xx + 757 pp. + 4 plates; text ill. 1950.

This entirely new textbook emanates from the Department of Anatomy of the University of Toronto from which, in 1937, a radically new approach to gross anatomy was published (*A Method of Anatomy*, by J. C. B. Grant). The present volume is somewhat less radical than its prototype, but it is novel enough and skilfully enough written to merit the serious attention of histologists. It has a chatty style, likely to be attractive to students.

There are a number of more or less bold departures from the customary presentation of histology. Considerable space is devoted to an interpretation of histology as a whole and to its methods. There is a chapter on tissue fluid and edema, one on sensory receptors, and one on articulations. The significance of numerous anatomical minutiae is discussed, and pathological conditions are frequently cited to emphasize their importance.

In keeping with the author's field of research, the chapter on bone is outstanding. Here, the photomicrographic illustrations could not be improved upon and the diagrams are significant and revealing. Yet some portions of the account are not entirely satisfying. The interpretation of osteoclasts as a fusion of surface cells "as a prelude to their death" will satisfy few critical readers. Greater emphasis might have been put on the essentially transitional nature of adult bone, which undergoes histological transformations (in spite of static external proportions) and remains in a constant state of flux throughout the life of the individual. Recent studies of the histology of adult bone indicate lifelong transformations of both fundamental and practical significance, which are but poorly recognized in current accounts of bone histology. Nevertheless, the description of bone in this text is commendable.

On the whole the book is splendid in format. The illustrations are uniformly good. The print, in double columns, is easy to read and free from error. The index is adequate. The organization of the material and the style, while both unusual, are refreshing departures from currently popular presentations. It is an unusually interesting first edition and should assume a respectable position in its field as it stands. It should be useful both to students and to instructors interested in new viewpoints.

F. N. LOW

A HISTOLOGY OF THE BODY TISSUES, *with a consideration of their function.*

By Margaret Gillison; foreword by R. C. Garry. Williams & Wilkins Co., Baltimore (made in Great Britain). $3.50. xiv + 220 pp.; ill. 1950.

This small cloth-bound volume of unusually neat appearance is a commendably brief and clear presentation of elementary histology and physiology. The fundamental body tissues are described with considerable emphasis on function. Organology is omitted. The illustrations are line sketches and wash drawings of micro-preparations. Its content is necessarily limited, but sacrifice of accuracy has been kept at a minimum. It is easy to read, and should be very useful to students in physiotherapy and physical education, for whom it has been prepared.

F. N. LOW

THE PLACENTATION OF THE PRONGHORNED ANTELOPE (ANTILOCAPRA AMERICANA). *Bull. Mus. comp. Zool. Harvard Coll. Vol. 101, No. 5.*

By George B. Wislocki and Don W. Fawcett. Museum of Comparative Zoology at Harvard College, Cambridge. 75 cents (paper). ii + pp. 545–560 + 3 plates; text ill. 1949.

ANIMAL PHYSIOLOGY

THE PHYSIOLOGICAL BASIS OF MEDICAL PRACTICE. *Fifth Edition.*

By Charles Herbert Best and Norman Burke Taylor. Williams & Wilkins Co., Baltimore. $11.00. xiii + 1330 pp.; ill. 1950.

Schools of medicine should give serious consideration to the suggestion that the requirements for entrance include examinations for brawn as well as brain. Textbooks, particularly such as this one, have now reached the size where the student just doesn't tuck them under his arm and carry them home—a van is needed. It has been also said that this textbook is now too large for a handbook and too small for an encyclopedia. Like Topsy it "just growed," and one may suggest that if subsequent editions continue to "just grow" they be published in 2 volumes.

Nevertheless, Best and Taylor's *Physiological Basis of Medical Practice* is one of the major textbooks of physiology. Its readability, illustrations, bibliography, and indexing make it a reference book of exceptional merit. Although, as pointed out elsewhere, there is a tendency in some departments to move away from these larger textbooks to those that present in more simple fashion the fundamentals, it is my opinion that both types should be included in the library of every medical student. In this edition (4th ed., *Q.R.B.*, 22: 162), most of the sections have been expanded by the inclusion of much new material that has been published during the past 5 years and the addition of more than 100 new illustrations.

DAVID B. TYLER

EXPERIMENTAL PHYSIOLOGY. *Revised Edition.* *By Maurice B. Visscher, Ernest B. Brown, and Nathan Lifson. Burgess Publishing Co., Minneapolis.* $2.75 (paper). v + 126 pp.; ill. 1950.

This manual for a laboratory course in physiology is among the best that this reviewer has seen. It contains clear descriptions for over 90 experimental procedures, organized under 9 general headings. Included are exercises for the demonstration of the general properties of protoplasm; the mechanisms of muscular activity, respiration, and nervous activity; the physiology of the circulatory system, sensation, and gastrointestinal function; and a number of experiments for studies of metabolism, internal secretion, and urine secretion.

It is exceptionally well written, well illustrated and organized, and contains an appendix of technical data and useful information for the student. This manual will serve very well as a guide for those who have the responsibility of setting up a laboratory course in physiology.

DAVID B. TYLER

VERGLEICHENDE PHYSIOLOGIE. *Band IV: Hormone. Lehrbücher und Monographien aus dem Gebiete der exakten Wissenschaften. Reihe der experimentellen Biologie—Band IX.* *By W. von Buddenbrock. Verlag Birkhäuser, Basel.* Swiss fr. 47.50 (cloth); 43.50 (paper). 492 pp.; ill. 1950.

This is the fourth volume of a projected six-volume series in comparative physiology, but is first to appear in point of time. A large amount of information is presented here in a condensed, organized, yet readable form. In bringing together endocrinological observations from a variety of zoological classes, the book covers a field not at all well represented by anything in English. Readers whose principal interest is the mammal, bird, amphibian or fish, respectively, will find their own literature well set forth, and will be adequately guided to that of the others. In view of the history of the manuscript, it seems miraculous that the author has been able to include, up to the last three or four years, so much of the old and the new literature. A section on invertebrate hormonal relationships is a good introduction to this rapidly advancing field. There are very numerous and excellent line drawings and charts, and this volume of the enterprise is heartily recommended.

H. N. CATCHPOLE

HÉMOGLOBINE ET PIGMENTS APPARENTÉS. *Myoglobines, Catalases, Peroxydases, Cytochromes, Porphyrines, Pigments Biliaires. Étude Physiologique et Pathologique.* *By Henri Bénard, Alfred Gajdos, and Marguerite Tissier. Masson & Cie., Paris.* 1350 fr. viii + 350 pp. 1949.

This is the third volume to appear in the period of one year on the subject of hemoglobin and related pigments, evidence of current and widespread interest and activity in this field. The Barcroft Symposium, *Haemoglobin* (Interscience, New York, 1949) is a collection of essays by various workers on current points of attack and current concepts, with major emphasis on kinetics and structure. *Hematin Compounds and Bile Pigments*, by Lemberg and Legge (Interscience, New York, 1949), is a massive review mainly of the biochemistry of these pigments. The present volume combines the physiological, biochemical, and clinical aspects.

While the subject matter is roughly similar to that in the book by Lemberg and Legge, the emphasis is somewhat different. After a brief introductory chapter on porphyrin chemistry, there is a more extensive one on hemoglobin and its compounds. Some of the topics presented in this chapter are: the problem of the hemeglobin linkage, inter- and intra-species differences of the hemoglobins, the preparation of denatured globin (adapted from the Anson and Mirsky procedure), in vivo synthesis of porphyrins and globins, the absorption spectra of hemoglobin and of several of its derivatives, the role of hemoglobin in respiration, hemochromogens and hemalbumins. The third chapter, on

clinical applications, contains detailed descriptions of some of the methods used clinically for the estimation of total hemoglobin concentration in the blood and a critical evaluation of these methods, a discussion of hemolysis and an extensive section on clinical syndromes of hemoglobinemia and hemoglobinuria. In the latter section there are described such varied disorders as paroxysmal and march hemoglobinuria, the Marchiafava-Micheli syndrome, and carboxy-, sulf-, and methemoglobinemia. The discussion of the relationship between hemoglobinemia and hemoglobinuria is well handled. A brief chapter on myoglobin is followed by a more extensive one on the metalloporphyrins which play a role in intracellular oxidations. This covers catalases, peroxidases, and the cytochrome—cytochrome oxidase system; methods of preparation, physical and biochemical properties, and absorption spectra are presented and discussed. The sixth chapter is on porphyrins, porphyria and porphyrinuria, and the last chapter is on bile pigments. In all chapters there are numerous figures illustrating absorption spectra and structural formulas.

In general, the discussions, particularly those on the clinical problems, are clearly and carefully presented, and the authors appear to have taken pains to give not only evidence for but also evidence against current hypotheses. Literature references are copious (there are approximately 1200) and fairly complete up to 1948, although there are some unfortunate omissions. There are also a number of minor typographical errors and a serious printer's error in the omission of all entries under L in the author index. The subject index, though short, is useful.

In spite of its shortcomings, this book is a worthwhile addition to the literature on hemoglobin. Though written for physicians, it is by no means a clinical book. It should be of interest to biochemists and biologists as well as to clinicians.

F. CHINARD

PHYSIOLOGY OF HEAT REGULATION AND THE SCIENCE OF CLOTHING.

Edited by L. H. Newburgh. W. B. Saunders Co., Philadelphia. $7.50. viii + 457 pp., ill. 1949.

The various chapters in this book come from the pens of those Americans who have contributed most to the firm establishment of this new field in applied physiology. It is destined, therefore, to be not only the best book which has appeared on the subject, but also its best known classic. It is the greater pity, on that account, that the volume shows no trace of editorial management. It may well be that editorial energies were exhausted by three years or more of forcing experts in experimental work to the desk job of reporting their conclusions; but though the general reader may be prepared to forgive the marked overlap between chapters, he will find it more difficult to condone the multiplicity of units employed, variation in quantitative expression, and hasty proof-reading. He might also expect the editor to have provided a perspective of this new field in relation to the general field of physiological endeavor.

Chapter 1, by Frederick R. Wulsin, gives an excellent anthropological review of adaptations to climate made by various non-European peoples in clothing, housing, and mode of life. It should serve to remind enthusiastic physiologists that many good ideas are not new: it should also warn enthusiastic anthropologists that human habits are not irrefutable indices of environmental conditions.

One could wish that Chapter 2 had been expanded, so that the newcomer could have had the benefit of C. P. Yaglou's experience in the actual procedures of thermometry, instead of mere references to literature. This chapter might have been more thoroughly integrated with the succeeding one by J. D. Hardy, partly in the interest of continuity, and also because of Hardy's wide experience and interest in thermometric procedures. The latter chapter sets out the physical basis of heat transfer, in detail which may well bewilder the non-physical reader, but which is, nevertheless, well worth having. It is a pity that the formulae for the calculation of radiation exchange with the sun, sky, and terrain described by Blum in the National Research Council wartime publication (which was, to some extent, the progenitor of the present volume) were not included.

For physiologists, Chapter 4 may well be the most welcome in the whole book, for it is here that the doyen of environmental physiology, H. C. Bazett, sets out in characteristic fashion the viewpoints derived from a lifetime of constant, meticulous endeavor, in the course of which few of his tissues have escaped the probing of his thermocouples, and few of his acquaintances the keen edge of his ideas. Seventy-eight pages is a small compass for the volume of ideas emanating from Bazett's lifetime, so that the style is not easy; but students will return again and again for many years to this chapter for refreshment of understanding.

In Chapter 5 Sid Robinson deals with the physiological adjustments to heat, and in the next C. R. Spealman does the same for cold. The latter is disappointingly short, the former disappointingly chary of conclusions. Both authors have every right to emphasize personal conclusions reached in the course of their wide experience. It is to be hoped that readers will not be deterred by their diffidence.

Chapters on regional heat loss (Richard Day), extreme tolerances (L. P. Herrington), and comfort indices (C. P. Yaglou), complete Part I, which deals with the basic physiology.

Part II deals with clothing as a thermal barrier, in three fairly long chapters. The first, by Lyman Fourt and Milton Harris, describes the thermal properties of

fabrics, their measurement, and their determinant factors. This information, fundamental to the intelligent design and use of clothing to the best thermal advantage, is set out in clear, logical fashion. Reference is made to parallel developments in Canada and the United Kingdom, and the relationship is given between the different systems of units employed.

The second chapter in Part II deals with specific studies of clothing assemblies under the various environmental conditions of desert, tropics, dry cold, wet cold, and water. It is a symposium by several authors, which though very good in its individual sections, would have greatly benefited by editorial integration. (Users should beware of a wrong sign in equation 7 on p. 361.) The concluding section of this chapter deals with the very important problem of keeping hands warm in cold environments, but with a mathematical virtuosity which may well daunt the average reader.

The final chapter, like the first, is geographical in its outlook. It is essentially a presentation by Paul A. Siple of the practical methods developed by the U. S. Quartermaster for determining the clothing requirements in all parts of the world, in the light of the considerations set out in the earlier chapters. It is possible that the reader might miss this latter point, however, for little specific reference is made to the research findings which led to the decisions reported; and he may be left with the curious impression that adequate practical methods of meeting problems were developed without all the detailed enquiries reported in earlier chapters. This was not the case, and certainly not the impression that the author intended to create.

All in all, this volume is invaluable and a classic. It remains a pity it was not given the final polish it so deserved.

DOUGLAS H. K. LEE

THE FUNCTION OF THE THYROID GLAND. *American Lecture Series. Publication Number 40.*

By J. H. Means. Charles C. Thomas, Springfield, Ill. 90 cents (paper). iv + 37 pp.; ill. 1949.

CHEMICAL DEVELOPMENTS IN THYROIDOLOGY.

By William T. Salter. Charles C. Thomas, Springfield, Ill. $2.00. viii + 87 pp. 1950.

The discovery of agents which impede the synthesis of the thyroid hormone and the application of radioactive iodine to problems of iodine metabolism have led to interesting developments in the field of thyroid physiology. Two outstanding workers in this rapidly growing branch of endocrinology have published brief but extremely stimulating reviews. Although much of the ground covered by both monographs is identical, they are written from different viewpoints. Means writes as a clinician, Salter as a pharmacologist. That both lectures be read is highly recommended not only to the specialist, but to anybody interested in the general problems of the correlation of body functions. In discussing the use of radio-iodine Salter stresses an important point, overlooked only too often in the current enthusiasm for the use of radioisotopes as tools for biological research. Salter emphasizes the importance of determining the specific radioactivity of iodine in tissues, that is, the ratio of the administered radioactive iodine to the total amount of iodine present. It is obvious that such measurements yield more information than the measurement of radioactivity alone. "More and more stress, therefore, must be laid upon the combination of radio-tracer measurements with classical microchemical determinations, so that the experiment may have a true physiologic significance."

Means closes his lecture with some remarkable ideas on the nature of Graves' disease, ideas which he himself describes as "a flight of fancy." His concept of Graves' disease is that of a pathologic response to maladaptation of the patient to his environment. Many aspects of the natural history of Graves' disease are explicable by such a theory. This is true, for instance, for the self-limitation of the disease, which has puzzled clinicians for decades. The format of both monographs is very pleasing and both contain useful bibliographies.

WALTER FLEISCHMANN

THE INFLUENCE OF LIGHT AND DARKNESS ON THYROID AND PITUITARY ACTIVITY OF THE CHARACIN ASTYANAX MEXICANUS AND ITS CAVE DERIVATIVES. *Bull. Amer. Mus. nat. Hist., Volume 93: Article 7.*

By Priscilla Rasquin. American Museum of Natural History, New York. 75 cents (paper). Pp. 497–532 + 6 plates; text ill. 1949.

THE PRODUCTION OF ANTIBODIES. *Monograph of the Walter and Eliza Hall Institute, Melbourne. Second Edition.*

By F. M. Burnet and Frank Fenner. Macmillan Co., Melbourne, Australia; New York. $3.00. viii + 142 pp. 1949.

In this second edition of Burnet's well-known book on the production of antibodies, the authors emphasize that they approach this problem as biologists, not as chemists. Contrary to most immunochemists, they believe that antibody production continues after the antigen has been eliminated from the body, and that antibodies are also produced by the descendants of the cells originally stimulated. Burnet and Fenner base their view on the fact that immunity sometimes persists for many years. They do not see "any conceivable storage space in the changing population of lymph or spleen cells where the antigen can be stored" for such long periods. The reviewer admits that ten years ago

it was difficult to believe that the antigen remains in the site of antibody production for many years. However, since that time it has been proved by Felton, by McMaster and Kruse, and by Coons and others that pneumococcal polysaccharide antigens are retained in the organs of mice for many months. It is not difficult, therefore, to assume a similar deposition of other antigens. In order to explain the formation of antibodies in the absence of antigen, Burnet and Fenner assume that the antigen modifies the globulin-producing enzymes, so that these produce antibodies instead of the normal globulins. If this were true, antibody production would be due to a mutation of the globulin-producing cells. It is difficult to accept this view, since we know that immunity is not transmitted to the descendants of an immunized organism.

In spite of my own different viewpoint, I consider the book of Burnet and Fenner to be one of the most stimulating treatises on immunology. The authors present the problem clearly and impressively. Their book is written with the enthusiasm of men who are convinced that they are right. The book contains a wealth of observations unpublished elsewhere. The reviewer has learned many new facts in reading the book and recommends it highly to all persons interested in immunological problems.

FELIX HAUROWITZ

HISTAMINE ANTAGONISTS. *CBCC Review No. 3. By Frederick Leonard and Charles P. Huttrer. Chemical-Biological Coordination Center, National Research Council, Washington, D. C.* $1.50 (paper). 122 pp. 1950.

ANIMAL NUTRITION

A STORY OF NUTRITIONAL RESEARCH. *The Effect of Vitamin A and D and Toxamins on Bones and the Nervous System. The Abraham Flexner Lectures, Series Number Nine. By Sir Edward Mellanby. Williams & Wilkins Co., Baltimore.* $5.00. viii + 454 pp.; ill. 1950.

This volume consists of the Flexner Lectures, delivered in 1947 at Vanderbilt University. It describes the development of the author's ideas, experimental studies, and their interpretation, over a period of thirty-five years. The title is well chosen to describe the subject matter of the story, which is an account of the author's own researches. It is the history of a mind during a distinguished research career.

The historical setting for Sir Edward's strictures on the cereals as rickets-producing foods would have been improved by brief mention of certain studies which antedated his investigations. Reference is made to extensive studies which made it clear that not only cereals, but other seeds of plants, as well as muscle meats and glandular organs of animals, are so deficient in calcium that this element is the limiting factor when any one of them serves as the sole source of nutrients. Before the existence of toxamins or phytic acid were incriminated as disturbers of calcium assimilation, the physiological importance of keeping the ratio between calcium and phosphorus in the diet within certain ratios was well known. Also, the regulatory action of vitamin D in safeguarding calcium and phosphorus metabolism when the ratios between these elements in the diet were unfavorable, had become clear. Mention of these facts would have changed considerably the author's account of the role of phytic acid in the etiology of rickets.

These omissions are mentioned in the interest of the readers of the book. Even with these omissions of historically important references to the work of others, the book is a brilliant exposition of notable researches.

E. V. MCCOLLUM

VITAMINOLOGY: *The Chemistry and Function of the Vitamins. By Walter H. Eddy. Williams & Wilkins Co., Baltimore.* $6.00. vi + 365 pp.; ill. 1949.

The present monograph on the chemistry and function of the vitamins has been designed primarily for the student. As such, it provides the latest treatment (1949) of the rapidly growing field of vitaminology in a single volume, which is well documented, with references to the most recent articles. Even so, the new developments dealing in the structure of vitamin B_{12} and its cobalt component are lacking. Apparently, the book must have already been in press when these findings were first being reported.

Each vitamin is discussed in an individual chapter, and each chapter is divided into three sections: function; chemical nature; and evaluation for human and animal use. The author has done a good job in culling and assembling the important observations and findings on each of the vitamins, and he presents this material in a simple and clear style, with literature citations. A glaring omission, however, is the failure to provide any sort of index to authors, since the latter are not included in the regular index. Although there is a distinct tendency to emphasize the medical nutritional aspects, there is an adequate treatment of mechanisms of action. However, the discussions of chemical nature and assay leave much room for futher expansion.

In evaluating this monograph, the question that arises is how this new volume compares with H. R. Rosenberg's *Chemistry and Physiology of the Vitamins*. The answer, if one is fair in making such a comparison, seems to be that Rosenberg's work is a far more thor-

ough and scholarly one, covering virtually all topics of vitamin research from all possible approaches, with special emphasis on the chemistry and physiology of the vitamins. The important contribution of Eddy's book is his up-to-date coverage. Used in conjunction with Rosenberg's volume (1945), it can serve as an excellent foundation and working source in vitaminology treating the literature to 1949.

ALVIN NASON

INVESTIGATIONS OF HUMAN REQUIREMENTS FOR B-COMPLEX VITAMINS. *Bull. natl. Res. Coun., No. 116.*

By Max K. Horwitt, Erich Liebert, Oscar Kriesler, and Phyllis Wittman; with the supervision of the Committee on Nutritional Aspects of Ageing Food and Nutrition Board, Division of Biology and Agriculture. National Research Council, National Academy of Sciences, Washington, D. C. $1.00 (paper). vi + 106 pp.; ill. 1948.

This monograph represents a detailed report of a three-year study to ascertain minimal requirements for thiamin and riboflavin of older versus younger men, with reference in particular to the influence of low and high intakes of these vitamins on mental disease. The report is divided into a number of sections: Description of Procedure, Biochemical Observations, Chemical Observations, Neurological Observations, Psychological Observations, and Summary and General Conclusions. It is apparently a forerunner to even more detailed aspects of the present study, to appear from time to time in appropriate scientific periodicals. The present monograph is well written and well organized. The purpose and plan of the experiments, as well as a large mass of data, are clearly presented in simple, straightforward terms. Although a minimum of interpretation has been made, some definite conclusions can be drawn from the evidence.

ALVIN NASON

GENERAL PHYSIOLOGY

COPPER METABOLISM. *A Symposium on Animal, Plant and Soil Relationships Sponsored by The McCollum-Pratt Institute of The John Hopkins University.*

Edited by William D. McElroy and Bentley Glass. Johns Hopkins Press, Baltimore. $6.00. viii + 443 pp. + 1 folding table; text ill. 1950.

The McCollum-Pratt Institute, which sponsored this symposium, was organized for the purpose of studying the biological roles of those nutrients which are variously known as trace, minor, or micronutrient elements. In this symposium a significant contribution has been made to an overall understanding in this field. Papers were presented by recognized authorities and dealt with the chemical properties of copper which affect its formation of organic complexes; the copper-protein enzymes; the copper metabolism of invertebrates, vertebrates (including humans), and plants; interrelationships of copper metabolism with molybdenum and other elements; and the copper content of plants as influenced by various soil and climatic factors. Both theoretical and practical aspects of these topics were considered, although the emphasis was upon the more theoretical and fundamental aspects. The discussion which followed each presentation is included, and the whole is brought together and integrated in a well-written summary. Although much of this information had been published elsewhere, this publication is very worthwhile because of the manner in which the overall subject is integrated.

On the whole, the individual subjects are presented in an interesting and clear fashion and are well-documented with illustrations and citations to the original literature. The usefulness of the book is enhanced further by the inclusion of appropriate indexes. In sponsoring this symposium the staff of the McCollum-Pratt Institute has performed a service which their colleagues should find useful and which should do much to further research in this interesting and important field.

G. FRED SOMERS

CELL PHYSIOLOGY AND PHARMACOLOGY.

By J. F. Danielli. Elsevier Publishing Co., New York, Amsterdam, London, and Brussels. $3.00. x + 156 pp.; ill. 1950.

This book is based upon a series of lectures given by the author at University College in London. The primary function of the book is, according to the Preface, to indicate "some of the important factors, on the cellular level, which must be considered by students of drug action."

The book is divided into six chapters, the first dealing with the cell as a physico-chemical unit. Chapters 2 and 3 discuss the problems of the action of drugs from the point of view of surface chemistry and membrane permeability. The fourth chapter discusses the enzymology of drug action. The fifth considers the action of narcotics and the various possibilities which have been entertained to explain their effects. The sixth chapter, which represents the author's development of his central thesis, is entitled Responses of Cells on the Biological Level. Here the author seeks to emphasize that the investigation of the pharmacological action of drugs need not be confined to purely chemical considerations. The structured nature of the cell presents a type of geometrical specificity which demands investigations aimed at localizing the site of the action of a particular compound.

To many biological readers it may perhaps appear that the continual emphasis by the author of the struc-

tured nature of the living cell belabors the obvious. It is nevertheless difficult to avoid agreeing with the author that many investigators who normally concern themselves with mechanisms of action have not yet made as much use of this unique property in the design of their experiments as its obviousness would appear to demand. Another fundamental feature often ignored, not only by pharmacologists, but also by cellular physiologists, is that cells are self-duplicating systems composed of units which can be classified in terms of their dispensability for the duplication of another cell. Unlike a prominent textbook in cellular physiology, which does not include the word "gene" in its index, the present volume, it is pleasant to report, contains almost as many references to the term gene as it does to enzymes.

In summary, it may be said that the introduction by Danielli of biological concepts should stimulate pharmacological research along fruitful lines. In view of its possible value, it is all the more to be regretted that greater care was not exercised in the presentation of the material.

The book shows many evidences of hasty composition. Typographical remissions are more frequent than they should be, and due to poor labeling, many of the graphs confuse more often than they illuminate. Further, the author has tended to cite researches which he has apparently not had the time or patience to digest thoroughly. Thus we find the following rather remarkable statement, "There is a good deal of evidence available now suggesting that mutations, whether they be of nuclear genes, or of plasma genes [sic], may commonly take place under the action of drugs such as penicillin, sulfonamides, arsenicals, etc., and thus give rise to strains of cells (usually of microorganisms) which are resistant to the drug concerned" (p. 143). In point of fact, the considerable amount of evidence now available leads to quite the opposite conclusion. Most competent investigators in the field are agreed that the apparent increase in mutations toward such substances as penicillin and sulfanilamides is due to the fact that these substances are acting as selective agents for randomly occurring mutations, the frequency of which is the same whether the drug is present or absent.

The danger of too close a dependency upon material prepared for oral delivery is all too often exhibited in this work. Sentences and paragraphs appear which must have sounded fine in the telling but which do not withstand the critical analysis made possible by their greater permanence in the printed form. There are far too many demonstrations of the possibility of constructing proper English sentences which transmit little or no information.

It is to be hoped that Professor Danielli will take the opportunity of a second printing of this work to increase the value of his contribution to the level which it deserves.

S. SPIEGELMAN

BIOPHYSICS

X-RAY TREATMENT—*Its Origin, Birth and Early History.*

By Émil H. Grubbé. Bruce Publishing Co., Saint Paul and Minneapolis. $3.00. xii + 154 pp.; ill. 1949.

This is a historical sketch of the early development of x-ray equipment and x-ray therapy in America, written by one of the pioneers. In the summer of 1895, the author was in business as an assayer and refiner of rare metals. He was paid for some of his consultant work with metallic platinum, and went into the business of manufacturing vacuum tubes. Most of the tubes were for incandescent lamps, but he and his associate, Albert Schmidt, also made Geissler and Crookes tubes, to order. At the very time when Roentgen was doing his memorable experiments and was duplicating Lenard's work with fluorescent chemicals, Grubbé and Schmidt were doing the identical things in Chicago. Roentgen discovered the x-ray on November 5, 1895, reported it to the Physical Institute of Würzburg on November 6, and it was published on November 8, 1895. When Roentgen announced his discovery, Grubbé was one of the few in the world with the facilities and training to verify and immediately to utilize those findings. It is the author's opinion that he was exposed to x-rays several years even before they had been discovered, as he had already been working with Crookes tubes and other x-ray-producing equipment. It was usual to test the x-ray tubes by observing the clarity of the shadow of the hand interposed between the tube and fluorescent screen. As a result of this procedure, the author received a severe and painful x-ray burn in January of 1896. A medical student at the time, the author showed his radiation-damaged hand to some of his professors at the Hahnemann Medical College. The doctors, especially Dr. J. E. Gilman, were impressed with the possibilities of utilizing the biologic action of of the new rays to treat disease. Within a few days, the doctors from the medical college sent several cancer patients to be treated with x-rays. The author maintains, therefore, that x-ray therapy was initiated on Wednesday, January 29, 1896, and in Chicago. The work was widely recognized and utilized after the author graduated as a physician in 1898, and became Professor of Roentgenology in the medical college.

The following chapters discuss the x-ray burns suffered by Dr. Grubbé, the early history of x-ray therapy, a critique of x-ray treatment, describe early x-ray equipment, list the pioneers of the x-ray, and include an essay on X-ray Therapy Tomorrow.

TITUS C. EVANS

COSMIC RADIATION AND ITS BIOLOGICAL EFFECTS. *Second Edition. Revised and Augmented.*

By Victor F. Hess and Jakob Eugster. Fordham

University Press, New York, N. Y. $4.00. viii + 178 pp.; ill. 1949.

This is a translation and revision of an earlier book published in Zürich in 1940. Divided into two sections, it deals first with the physical studies of cosmic radiation made by the senior author, which led to an award of the Nobel Prize to him in 1936. The second half discusses the variety of experiments which have been carried out to determine whether cosmic radiation has any detectable biological effects. Although no positive experimental evidence has been forthcoming, with the possible exception that cosmic showers may have a stimulating effect on tumor cells of white mice, the junior author, who has written the biological portion of the book, is reluctant to give up the idea that cosmic radiation is a potent factor in governing the activity of cells.

C. P. SWANSON

MEDICAL PHYSICS. *Volume II.*

Editor-Chief: Otto Glasser. Year Book Publishers, Chicago. $25.00. xxvi + 1227 pp.; ill. 1950.

The editors of this compendium have followed what seems to be a wise course when faced with the problem of revising the previous edition of *Medical Physics*. The choices were to issue a second edition which would to a considerable extent duplicate many sections of the first edition, while the amount of new material to be added would cause the work to become a multivolume affair. Instead, the new material, together with revisions of a number of previous sections, have been put out as Volume Two.

A considerable number of the added fields represents subjects which underwent a very rapid development as a result of the war (particle accelerators, aviation medicine, isotopes, etc.), regarding which the only criticism one might have is that the selection of subjects is at times so miscellaneous that it is not quite clear for just what group of readers the compilation has been made. Perhaps this selection of purely clinical techniques blended with the physics of synchrotrons is intended to broaden as much as possible the base of the work and to increase the number of readers. Practically without exception, the articles are written by well-qualified authors, and are very useful summaries of the present state of a field and excellent sources of bibliographical information.

L. J. MULLINS

BIOCHEMISTRY

FUNDAMENTALS OF PHYSICAL CHEMISTRY *for Premedical Students.*

By H. D. Crockford and Samuel B. Knight. John Wiley & Sons, New York; Chapman & Hall, London. $4.25. xii + 366 pp. 1950.

The authors designed this textbook for biology and premedical students who have the usual background in undergraduate chemistry (general, qualitative, quantitative and organic chemistry) and who have a limited mathematical training. With these students in mind, the kinetic, rather than the thermodynamic approach has been principally used in the text. The book is quite readable, and contains the usual bibliography and sets of questions at the end of each chapter. It can be recommended for short courses in physical chemistry.

DAVID B. TYLER

OXIDATION-REDUCTION POTENTIALS IN BACTERIOLOGY AND BIOCHEMISTRY. *Sixth Edition.*

By L. F. Hewitt. Williams & Wilkins Co., Baltimore (printed in Great Britain). $4.50. viii + 215 pp.; ill. 1950.

A new edition of Hewitt's book, which has been a standard work for so long, is most welcome. The present edition has been expanded to include chapters on pH measurement, metabolic cycles and chain reactions, and chemotherapy and antibiotics.

ANNUAL REVIEW OF BIOCHEMISTRY. *Volume XIX. Editor: J. Murray Luck. Associate Editors: Hubert S. Loring and Gordon Mackinney. Annual Reviews, Stanford, Cal.* $6.00. xii + 596 pp. 1950.

The Annual Review of Biochemistry is by now so well known and appreciated that a lengthy description here is unnecessary. Volume XIX differs from its predecessors in not containing chapters of special interest to plant biochemists; such chapters have now been transferred to a companion volume, *Annual Review of Plant Physiology*, which appeared for the first time in 1950. Subjects like photosynthesis, which are of mutual interest to biochemists and plant physiologists, will in the future be shared between the two journals in some equitable manner. It is appropriate that the present volume should open with a tribute to the late D. R. Hoagland, the noted plant physiologist who served on the Editorial Committee and Board of Directors of Annual Reviews until his recent death, and who was ultimately responsible for the inception of an *Annual Review of Plant Physiology*.

The 22 chapters of the present volume cover a great range of topics and review somewhat over 4700 individual papers. In most cases, the reviewers have done a skilful job of organization and condensation. Some of them are able, in addition, to present a unified picture of progress and trends in their particular fields. The editors, in their Preface, reiterate that the re-

viewers are urged to omit papers not considered important and to emphasize in the discussion only those of outstanding significance. Notwithstanding the resulting incomplete coverage of the literature, the *Annual Review* continues to be the most useful compendium of biochemical literature available in the English language.

The contents of volume XIX are as follows: Biological Oxidations (V. R. Potter); Proteolytic Enzymes (M. Laskowski); Nonoxidative, Nonproteolytic Enzymes (P. P. Cohen and R. W. McGilvery); Carbohydrate Chemistry (M. L. Wolfrom and J. M. Sugihara); Chemistry of Lipids (H. J. Deuel, Jr.); Chemistry and Metabolism of the Steroid Hormones (G. Pincus); Chemistry of Amino Acids and Proteins (R. K. Cannan and M. Levy); Nucleic Acids, Purines, and Pyrimidines (G. Schmidt); Carbohydrate Metabolism (S. Ratner and E. Racker); Fat Metabolism (G. Medes); Metabolism of Proteins and Amino Acids (P. P. Swanson and H. E. Clark); Chemistry of the Hormones (A. White); Water-Soluble Vitamins (E. E. Snell and L. D. Wright); Fat-Soluble Vitamins (T. Moore); Nutrition (H. M. Sinclair); Muscle (F. B. Straub); Biochemistry of Neoplastic Tissue (C. Carruthers); Chemical Composition of Blood Plasma and Serum (H. A. Krebs); Pyrrole Pigments (R. W. Lemberg and J. W. Legge); Immunochemistry (P. Grabar); Biochemistry of Antibiotics (H. E. Carter and J. H. Ford); Partition Chromatography (A. J. P. Martin).

ARTHUR W. GALSTON

PERSPECTIVES NOUVELLES DANS LA CHIMIE DES ÊTRES VIVANTS, I. *Actualités Scientifiques et Industrielles, 1073; Conservatoire National des Arts et Métiers, XLI.*

By Maurice Javillier, W. H. Schopfer, Y. Raoul, T. Wallace, Ch. Mentzer, W. Bladergroen, Paul Meunier and René Wurmser. Hermann & Cie., Paris. 1000 fr. (paper). 198 pp. + 6 plates; text ill. 1949.

This attractively printed and readable volume contains a series of articles on certain aspects of the chemistry of living matter. The articles are not written for specialists but may be of interest either as an introduction to certain fields or as a brief review of certain topics. Schopfer has written a very interesting contribution on the vitamins of soil. Investigations in this field began in 1937 when Muller demonstrated that the fungus *Mucor ramannianus* requires thiamin (or thiazol) for growth, but also that thiamin could be found in soil where this organism grows naturally. Subsequently, it has been shown that certain soils contain biotin, B_6, pantothenic acid, etc. It appears that there are many sources of the vitamins, but that the higher chlorophyll plants may play a major role. Equally interesting from another standpoint is the article by M. T. Wallace, Director of the Long Ashton Research Station, on the visual diagnosis of mineral deficiencies in plants. The excellent plates which accompany the article should be of considerable help in establishing the cause of difficulties in the back yard or in the fields.

Human vitamin deficiencies are discussed by Y. Raoul, particularly in relation to France during the years of the Occupation. Raoul emphasizes the importance of considering the total food intake as well as the vitamin intake. That relatively few cases of full-blown vitamin deficiencies did develop may have been due to the near starvation level of the general population; deficiency symptoms did appear in those who supplemented their rations with liberal amounts of canned or preserved foods. Levels of several vitamins in the blood are presented, and the significance of these levels is discussed.

Among other contributions are Mentzer's on natural and synthetic plant hormones, Bladergroen's on some applications of nuclear physics in biology, and Wurmser's review of oxidation-reduction systems and their importance to biological events. Finally, there is a survey article by Javillier on the evolution of the vitamin concept. This covers not only the nutritional aspects but also the more strictly biochemical ones; anti-vitamin effects of structural analogues are also briefly discussed.

F. CHINARD

THE BIOCHEMISTRY OF B VITAMINS. *Amer. Chem. Soc. Monograph No. 10.*

By Roger J. Williams, Robert E. Eakin, Ernest Beerstecher, Jr., and William Shive. Reinhold Publishing Corp., New York. $10.00. x + 741 pp. 1950.

This book provides the most thorough, critical examination which has yet appeared of the more fruitful investigations of p-aminobenzoic acid, biotin, the folic acid group, the nicotinic acid group, pantothenic acid, the vitamin B_6 group, riboflavin, thiamine, and other nutritional factors of doubtful status. The titles of the four sections into which the book is divided are: Characterization, Distribution, Assay and Biogenesis of B Vitamins; The Catalytic Functions of the B Vitamins; The Role of the B Vitamins in Animal and Plant Organisms; Analogues of B Vitamins and their Biological Activity. These accurately describe the character of the volume.

The authors have accomplished their purpose admirably. Biologists, physiologists, biochemists, pathologists, and pharmacologists will find this book well worth most careful study.

E. V. MCCOLLUM

VITAMIN METHODS. *Volume One.*

Edited by Paul György. Academic Press, New York. $10.00. x + 571 pp.; ill. 1950.

This is the most useful book on vitamin methodology yet to appear. It is designed to discuss and evaluate the various techniques for vitamin assay in sufficient detail to relieve the reader of the necessity of consulting other reference works. It accomplishes this aim to a remarkable extent. Because of the thoroughness of the discussions, the publishers have found it necessary to expand the projected one volume to two. The present volume discusses physical, chemical, and microbiological techniques; Volume II will deal with the techniques of animal assay, biometrics, and clinical aspects of vitamin deficiencies.

The organization of the book is unusual in that the assay techniques, rather than the vitamin, form the integrating units. In Chapter I, Eric T. Stiller discusses the various physical methods available for vitamin assay. This is followed by chapters on Chemical Methods (Paul György and Saul H. Rubin); Microchemical Methods (Otto A. Bessey); Microbiological Methods (Esmond E. Snell); and Optical Instruments in Vitamin Analyses (Erich Hirschberg). These 5 chapters cover more than 500 pages, about 60 per cent of which are taken up by the discussions of chemical and microbiological methods. The "horizontal" rather than "vertical" organization of the material will doubtless inconvenience those readers who are interested in obtaining a unified discussion of assay methods for a specific vitamin. However, since most laboratories are set up and equipped to utilize only certain procedures, the scheme of organization is eminently sensible and practical.

The descriptions of individual methods generally include discussions of the principles involved in the determination, the apparatus and reagents required, the procedure in detail, calculations, reproducibility and accuracy, and helpful "off-the-cuff" hints and comments. For those who may want to consult original papers, abundant references are supplied. Complete and convenient author and subject indices are also provided.

One may express the hope that the publishers will plan to provide periodic brief supplements to certain chapters, as new techniques and methods appear. If this is done, the present work should become established as a bible for researchers interested in performing vitamin assays.

ARTHUR W. GALSTON

MICROBIOLOGY

INTIMATE BACTERIOLOGY. *A Text and Laboratory Manual. Revised Edition.*

By Casper I. Nelson. Burgess Publishing Co., Minneapolis. $3.75 (paper). xi + 242 pp.; ill. 1949.

The present edition of this book (mimeoprinted; spiral binder) shows some improvements over the 1946 edition (*Q. R. B.*, 22: 362. 1947). Although the number of pages has been increased, the book is slightly thinner, owing to the use of better paper and smaller print. A number of the illustrations have been reduced in size, without loss of detail. There has been some revision of the text. The chapter on antibiotics and sulfonamides has been considerably improved. There is a new chapter on disinfectants.

As before, the book appears mainly addressed to the author's second course in bacteriology at the North Dakota Agricultural College, covering a wide range of topics in the bacteriology of daily life. It is as readable as before, but still exhibits a general looseness of statement and interpretation which is noticeable even in the new material. A more careful revision would have produced a sounder text, with little if any loss in readability.

WALTER C. TOBIE

MICROBIOLOGY.

By Florene C. Kelly and K. Eileen Hite; introduction by G. M. Dack. Appleton-Century-Crofts, New York. $6.50. xvi + 592 pp.; ill. 1949.

This book deals primarily with pathogenic bacteria, but includes chapters on the protozoa, fungi, actinomycetes, rickettsias, viruses, and spirochetes. It is designed for beginning students of infectious diseases in the broad sense.

Part 1 reviews briefly the nature of living organisms, and gives specific information on the character of the various groups of pathogenic microorganisms to be described. Included here is a chapter on the algae. Part 2 describes the methods of studying microorganisms, including the culture and identification of bacteria. It ends with a discussion of the basis of classification of bacteria, and a useful tabulation of distinguishing characteristics of the important bacterial species. Nutritions, respiration, and metabolism of bacteria are treated briefly in Part 3, and Parts 4 and 5 cover microbial populations and antimicrobial methods, respectively. The latter includes a discussion of asepsis and disinfection, as well as material on the therapeutic drugs of value in bacterial diseases. Part 6 is devoted to parasitism, pathogenicity, immunity, and related phenomena; and Part 7, a major portion of the book presents specific information on the various pathogenic agents and the diseases they induce. Part 8 may be described as an introduction to epidemiology and public hygiene. The Appendix includes an interesting and valuable section called Early Milestones in Microbiology. This consists of 6 pages of tabulated items, with date, name, and a brief description of a particular

discovery or development constituting the "milestone." Also included in the Appendix is a section on formulae for stains, culture media, and common reagents, to serve as a supplement to Part 2. Ample references, often to reviews, are tabulated in the Appendix and are grouped by chapters.

The book is well illustrated with line drawings and numerous halftone engravings. Many charts and tables are included. Discussions of the various topics are necessarily brief but are well balanced and clear.

As indicated by the title, an attempt has been made to present the pathogenic microbes in their proper perspective in relation to the world of microscopic organisms in general. Both the viewpoint and the attempt are highly commendable, and the fact that this broad concept is not maintained throughout does not detract from the value of the book. Reflecting the main interest of the authors, the work is primarily a textbook of pathogenic bacteriology. The general discussions, such as those contained in Methods of Studying Microorganisms, Microbial Populations, and Chemotherapy, deal almost exclusively with bacteria. Nevertheless, the material given on other disease agents is adequate for the purpose of the book, and is well handled. Taken as a whole, the book is an excellent introduction to pathogenic microbiology. It covers a wide field in a masterful fashion and will be found valuable to all students with interests within that field.

FRANCIS B. GORDON

THE EXAMINATION OF WATERS AND WATER SUPPLIES (*Thresh, Beale and Suckling*). *Sixth Edition.*

By Edwin Windle Taylor. The Blakiston Co., Philadelphia. $12.00. xii + 819 pp. + 2 plates; text ill. 1949.

This is the latest edition of a well known textbook and reference on the technology of potable waters. It is the most comprehensive single work available on the chemical, bacteriological, and biological analyses of water supplies. It discusses, with varying thoroughness, all phases of the behavior of water that might concern the analyst and supervisor: its geology, the factors determining potability, common techniques of chemical and bacteriological analyses, disinfection, filtration, corrosion control, algae and odor control, softening, and so on. A relatively large amount of space is spent in the interpretation of representative analytical data from British waters.

Like earlier editions, it is a useful compendium for reference. A great deal of experience is represented in the side comments the author makes, and in the extensive quotations from British reports and decisions. All moves along smoothly, and very informally. It makes good reading.

The book demonstrates a very interesting difference in the recent developments in sanitary engineering, chemistry, and biology in this country and in England. The American engineer, advanced operator, or research man now requires more fundamental information for his work. This is reflected by the papers appearing in the *Journal of the American Water Works Association* and other technical literature. This edition of *The Examination of Waters and Water Supplies* continues in the descriptive tradition.

The sections on the biology of waters, clean and polluted, are extremely elementary and poorly developed, despite the prevailing excellence of British work in this field. The 24 plates representing common plankton forms from different environments are very poor. It is doubtful that inexperienced workers will find them useful without supplementary descriptive keys.

CHARLES E. RENN

EXPERIMENTS IN BACTERIAL PHYSIOLOGY. *Revised Edition.*

By Perry W. Wilson and Stanley G. Knight. Burgess Publishing Co., Minneapolis. $1.75 (paper). iv + 55 pp.; ill. 1949.

This manual (mimeoprinted and with a spiral binder) contains 22 exercises for graduates and seniors in a one-semester course, permitting some selection of material. Although rather fine print is used, the reproduction is excellent. The main stress is laid upon chemistry and metabolic changes in the true bacteria, other microorganisms receiving much less attention. A good deal of stress is also laid upon growth, reproduction, and death. The manual was originally intended for use at the University of Wisconsin. It has also been adopted by other institutions, a fact understandable in view of its general excellence.

WALTER C. TOBIE

VIRUSES 1950. *Proceedings of a Conference on the Similarities and Dissimilarities between Viruses Attacking Animals, Plants, and Bacteria, Respectively. Held at the California Institute of Technology, March 20–22, 1950. Sponsored by the Institute's James G. Boswell Foundation Fund for Virus Research.*

By M. Delbrück and 22 other contributors. Division of Biology, California Institute of Technology, Pasadena. $2.50. 147 pp.; ill. 1950.

The reemphasis on d'Herelle's bacteriophages as bacterial viruses, and productive researches of the past decade have provoked two extreme viewpoints: first, that the phages are special forms with no relevance to plant or animal virus study; second, that for technical reasons, they are the only viruses worth studying. As the subtitle suggests, this book aims at exorcising both of these fallacies.

About two-thirds of the book consists of the Proceedings of the Conference, with contributions on plant viruses (J. G. Bald, F. C. Bawden, C. A. Knight, N. W. Pirie, H. K. Schachman, and J. M. Wallace), animal viruses (G. H. Bergold, R. W. Schlesinger, and R. E. Shope), and bacteriophages (including S. E. Luria, M. Delbrück, and their associates). These papers are often tantalizingly sketchy, and deal with a variety of rather special problems, but they are written and edited in a provocative and imaginative style which will elicit many fresh ideas.

The remaining 50 pages are headed Syllabus on Procedures, Facts, and Interpretations in Phage, which appears to be an effort to codify the lore and jargon of the school of phage research developed in this country under the leadership of Delbrück, Luria, A. D. Hershey, and others. A new admission to this code, of special interest in general biology and genetics, is the long-since described phenomenon of "true lysogenesis," or symbiotic association of bacterium and virus, for which several parallels have also been pointed out in plants and animals. The syllabus is not a laboratory manual, although many procedures are detailed, but is to be recommended as a guide to the current literature on the work of this school.

The short papers are such a pleasure to read that just one regret is manifest: each of this book's many readers will be sorry not to have been able to overhear this small group in its conferences around the campfires in Death Valley.

JOSHUA LEDERBERG

PARASITOLOGY

STUDIES ON HOOKWORM DISEASE IN SZECHWAN PROVINCE, WEST CHINA. *Amer. J. Hyg. Monog. Ser., No. 19, May, 1949. Supported by the De Lamar Fund of The Johns Hopkins University.*

By K. Chang and Co-Workers. Johns Hopkins Press, Baltimore. $3.00. x + 152 pp. + 9 plates; text ill. 1949.

This monograph describes the first major work on hookworm infection in China since the studies of the China Hookworm Commission nearly 3 decades ago It is the first of a series of reports on the prevalence, distribution, and importance of the intestinal parasites of man in Szechwan, one of the largest, richest, and most populous provinces in China. Following a general introduction and historical review, most of the book is devoted to reporting the relationships found between the major agricultural pursuits in Szechwan Province and the acquisition of hookworms by man. Contrary to the findings of the China Hookworm Commission in other parts of the country, the authors state that the cultivation of mulberry trees in Szechwan is not a major source of hookworm infection. Instead, agricultural methods employed in cultivating and fertilizing (with nightsoil) corn and sweet potatoes bring about ideal conditions for the transmission of hookworms. The report is concluded with a discussion of possible control measures, one of which is rather novel in that it involves merely a simple modification of the generally accepted manner of interplanting corn and sweet potatoes. Although primarily a technical report, interspersed are descriptions of terrain, case histories, and discussions of native customs and beliefs that make the book genuinely interesting and readable.

ALAN W. DONALDSON

INTRODUCTION TO PARASITOLOGY. *With Special Reference to the Parasites of Man. Eighth Edition.*

By Asa C. Chandler. John Wiley & Sons, New York; Chapman & Hall, London. $6.00. xii + 756 pp.; ill. 1949.

Again, as with earlier editions, the most remarkable feature of this book is the readable style of its author. There are other better reference books but none so capable of catching the interest and imagination of the young student as this textbook by Asa Chandler.

In general, the present edition is quite similar to the 7th (*Q. R. B.*, 20: 292. 1945) in organization and emphasis. Nevertheless, it has been rewritten materially in order to incorporate the many important contributions of the past 5 years. In regard to major additions, it will please many instructors of parasitology to observe that, brief though they may be, sections have been included on arthropod-borne bacteria, rickettsias, and filtrable viruses. An entire chapter is devoted to the spirochetes.

Details of classification, nomenclature, and morphology are intentionally omitted. The author maintains that an introductory textbook should be more concerned with fundamental principles. The success of his volume may be taken as proof of his wise judgment in the selection of the material to be presented.

M. M. BROOKE

HEALTH AND DISEASE

ANNUAL REVIEW OF MEDICINE. *Volume I.*

Editor: W. C. Cutting; Associate Editor: H. W. Newman; 29 contributors. Annual Reviews, Stanford, Cal. $6.00. viii + 484 pp. 1950.

This volume introduces a new member to the family of Annual Reviews. Its purpose is to present, principally for the clinical investigator, a critical evaluation of some of the more active fields of medicine. To quote from the Preface, "The authors have been urged to pitch their writings at a scholarly level, to include experimental background, and to avoid cookbook therapeutic recitals."

In this volume the following topics are reviewed: Infectious Diseases (L. A. Rantz); Diseases of the Gastrointestinal Tract (G. B. Eusterman and D. C. Balfour); Diseases of the Cardiovascular System: Medical (J. McMichael and W. W. Brigden); Diseases of the Cardiovascular System: Surgical (M. DeBakey); Diseases of the Kidneys (S. E. Bradley); Nutrition in Medicine (S. S. Kahn and F. J. Stare); Allergy (E. L. Keeney); Neoplastic Diseases (M. B. Shimkin); Diseases of the Reproductive System (J. C. Burch, H. T. Lavely, Jr., and O. W. Carter); Obstetrics (L. M. Hellman); Diseases of the Nervous System: Neurology (A. E. Walker); Psychiatry (J. C. Whitehorn); Diseases of Bones and Joints: Orthopedic Surgery (J. A. Key); Diseases of the Respiratory System (J. J. Singer); Physical Agents and Trauma: Shock and Burns (E. I. Evans); Anesthesia (J. A. Paulson and J. S. Lundy); Radiology and Radioactivity: Radiobiology in the Service of Medicine (R. R. Newell); Diseases of the Ear, Nose, and Throat (S. J. Crowe, W. E. Loch, and E. N. Broyles); Hematology: Blood Formation and the Anemias (G. Carpenter); Laboratory Aids to Diagnosis and Therapy (E. M. MacKay); Therapeutics and Toxicology (W. T. Salter). Also included is an annotated list of reviews in medicine, by E. M. MacKay. Since it is quite impossible to cover all fields of medicine in such a volume, this section will undoubtedly enhance the value of the volume. There are the usual very adequate author and subject indexes.

DAVID B. TYLER

MEDICINE. *The Patient and His Disease. Volume One.*

By A. E. Clark-Kennedy. Williams & Wilkins Co., Baltimore. $6.00. xii + 383 pp. 1947.

MEDICINE. *Diagnosis, Prevention, and Treatment. Volume Two.*

By A. E. Clark-Kennedy. Williams & Wilkins Co., Baltimore. $7.00. xii + Pp. 385–894. 1949.

The task of synthesizing and integrating the accumulated knowledge and experience in the entire field of medical science is one that requires an intellectual discernment and tenacity of effort that are indeed rare. The author's attempt at such a colossal job stems f rom his conviction that the field is now so vast, and the training in it so committed to the memorizing of isolated facts and techniques, that the potential doctor has neither opportunity nor inclination to develop an attitude of mind capable of grasping the basic principles of medical science, namely, the nature of the patient, and the meaning of his disease.

In the 6 chapters of the present volume, the writer has ignored the conventional boundaries of the medical disciplines and specialties, and, beginning with a basic consideration of matter and energy, conducts the reader through a series of learned discussions involving the principles of evolution, genetics, chemistry, physics, anatomy, ethics, philosophy, and religion (and indeed, every other branch of knowledge related in any way to medicine) in arriving at a clear picture of the central object of all medical art and science—man, with all his physical, mental, and emotional ills.

The logic and clarity of the presentation make the work thoroughly readable and understandable, but the fact that each sentence is so thought-provoking may extend the reading time beyond expectation. The deliberate avoidance of items to be memorized should appeal to the hurried, fact-ridden medical student.

The author's success in inculcating his desired attitude of mind can be measured only in terms of the future breadth of dissemination of his ideas, and the willingness of his readers to assimilate his philosophy. For the present, one can only say that his book is an admirable stimulus in the right direction.

B. AUBREY SCHNEIDER

Volume Two consists of a pleasant discursive discussion of a wide variety of medical topics, covering disturbances of both body and mind, at all ages of life, and under a considerable gamut of conditions, presented from a British point of view. For the medical practitioner who wishes to spend a pleasant evening or two reading about what he knows already (or at least has heard of before) the book may be recommended. Others will find it of very minor and incidental interest.

WALTER C. TOBIE

FORENSIC MEDICINE.

By Keith Simpson. A William Wood Book; Williams and Wilkins Co., Baltimore. $4.50. viii + 335 pp. + 2 plates; text ill. 1947.

Among the many avenues of medical practice and specialization, certainly one of the most exacting is that of medical jurisprudence. Half truths, quasi-scientific methods, and conjecture have no place in a realm where the legal status and rights of man, either living or dead, are so clearly involved.

This carefully prepared and thoroughly enlightening little volume is designed for the medical student or physician, at any level of training or experience, as a practical guide in the field of legal medicine. Although the work is developed around the British practices and legal procedures in dealing with unnatural death, the general principles and specific techniques of forensic medicine are applicable in any part of the world. The case histories and photographs, drawn largely from the author's own files, are striking contributions to the authoritative nature of the discussions.

Even though the reader may never be called upon to use any of the facts or techniques set forth in these pages, he will be well repaid for his reading time in sheer fascination alone.

B. AUBREY SCHNEIDER

THE MIRACLE DRUGS.

By Boris Sokoloff. Ziff-Davis Publishing Co., Chicago and New York (Prentice-Hall, New York). $3.00. 308 pp.; ill. 1949.

Antibiotics are the principal miracle drugs described in this book. Penicillin gets 4 chapters, and all other antibiotics a total of 6, a fairly reasonable distribution of attention. The sulfonamides and other synthetic drugs are almost "also rans." A large amount of interesting material is presented on the various antiinfective agents, especially on the preliminary steps which led up to their discovery, and the development of their clinical usefulness later. Important features of their manufacture are also considered. The book is written in a clear, easy style, with relatively little of the "saved-at-the-eleventh-hour" dramatics found in some popularizations of medical topics. References to the rather extensive bibliography are rather freely used. In general, this seems to be a book intermediate between a purely popular exposition, and a general technical account.

Several errors were spotted. Polymyxin (misspelled "polymyzin" on p. 295) was first described by Stansly in 1947, and was not discovered by Benedict and Stodola in 1948 (p. 216). Servetus, not "Servitus," is probably the early writer on the circulation of the blood mentioned on p. 250. The pigment pyocyanin from *Pseudomonas aeruginosa* (p. 69) was not first described in 1921, having been investigated chemically by Fordos as early as 1860. Such errors detract from the scientific accuracy of the book, even if they do not mar it appreciably for popular reading.

WALTER C. TOBIE

THE CIBA COLLECTION OF MEDICAL ILLUSTRATIONS.

By Frank H. Netter. Ciba Pharmaceutical Products, Summit, N. J. $6.50. 222 pp.; ill. 1948.

This atlas type of book is the compilation of the many sets of anatomical and pathological illustrations published by the Ciba Pharmaceutical Co. for the past several years. Each page contains a full color illustration of a specific subject, together with an explanatory text. A gem of conciseness, the volume summarizes salient features and leaves the myriads of less significant details to the specialist. Netter's full-page color illustrations are a departure from the usual type of black and white drawing seen in most scientific texts, and where necessary, microscopic and roentgenographic information is also presented. This book is unusual in its approach and is truly a thing of beauty. It has great teaching value; its color work attracts attention, and its clear-cut, accurate presentation enables one to grasp the subject-matter rapidly. A *Ciba Collection* in the hand is worth two standard pathology textbooks on the bookshelf.

WILLIAM E. LOECHEL

CARDIOVASCULAR DISEASE. *Fundamentals, Differential Diagnosis, Prognosis and Treatment.*

By Louis H. Sigler. Grune & Stratton, New York. $10.00. xxii + 551 pp.; ill. 1949.

It is difficult to imagine the need that can be filled by Sigler's *Cardiovascular Disease*. Several brilliant clinical textbooks in this field are already available and well known (e.g., those of White, Levine, Lewis, etc.). Those authors speak with authority and clarity, whereas Sigler writes in an undistinguished manner. The fundamental anatomy and physiology of the circulation are treated in a perfunctory and fragmentary fashion. The quality of thought is well exemplified by an almost meaningless definition of shock: "Shock may be defined as a state of general anoxemia, anoxia and toxemia associated with hemostasia in the capillary and venular radicals of the vascular system induced by severe bodily trauma or emotional disturbances and exhibiting itself in characteristic pathologic changes and clinical manifestations." There is inadequate effort to include recent advances in the field and, with some exceptions, the book could have been written and the references collected equally well at least three to five years ago. Specialized diagnostic tools are but briefly presented, and the extremely important methods and interpretations of electrocardiography are considered by the author to be fully covered by reference to his own 1944 textbook on that subject. However brilliant this latter book may have been when first published, several recent advances (especially the wide use of unipolar limb and precordial leads) render it inadequate as sole reference. There are many additional serious criticisms of the annotation and bibliographical selections. Taussig's clinical monograph on congenital heart disease, for example, is not mentioned, even though a chapter is devoted to this group of conditions.

The clinical manifestations and treatment of cardiac disease are related in an adequate fashion. It is possible, therefore, that an audience will be found among practitioners who rely on others for technical diagnostic procedures and who are unconcerned with nonclinical or controversial aspects of cardiology.

E. CONVERSE PEIRCE, II

HEMORRHAGIC DISORDERS. *A Guide to Diagnosis and Treatment.*

By Paul M. Aggeler and S. P. Lucia; lettered and illustrated by Phylura Gibbs, Helene Cleare and Jean Thompson under the supervision of Ralph Sweet. University of Chicago Press, Chicago. $10.00. xii + 112 pp.; ill. 1949.

This book gives a simple, remarkably concise account of the subjects treated, without any unnecessary verbiage. It is, nevertheless, clearly and authoritatively presented, and the material is entirely adequate for the purposes intended. The text is supplemented

by many tables, diagrams, and illustrations, many in color, which clarify and emphasize the points of major importance.

The material is presented in four sections. The first section (9 pp.) deals with the physiology of hemostasis. In the second section (14 pp.) the technic of the usual hemostatic tests is given in detail. A statistical analysis of the figures obtained in normal subjects is included. Only those tests which are actually used routinely in diagnosis or in the management of patients are included. The third section (48 pp.) includes a brief account of each of the hemorrhagic disorders of any importance, including the purpuras which are due primarily to vascular rather than hemostatic disturbances. This covers the etiology, if known, the clinical manifestations, the nature of the hemostatic defect, the results to be anticipated from the hemostatic tests, and treatment. Much of this is based on the authors' own observations. The fourth section (14 pp.) considers the available therapeutic procedures and preparations, primarily from the standpoint of their applicability. A number of highly questionable values which have been in use are discussed and rejected. The technic of determining blood groups, matching donors, and administering transfusions is not included. There is a good representative bibliography.

The book is intended for the instruction of the uninitiated, technicians, medical students, or physicians with little specialized knowledge of the subject. It is presented in a relatively elementary manner, and the more technical and controversial phases of the subject have been largely avoided. It is well suited for this purpose. A surprising amount of factual information has been included, and many who are fairly familiar with the field will find it useful for reference and quick reorientation.

PAUL W. CLOUGH

HEMATOLOGY FOR STUDENTS AND PRACTITIONERS. *Revised Second Edition.*

By Willis M. Fowler; with a chapter by Elmer L. Degowin. Paul B. Hoeber, Medical Book Department of Harper & Bros., New York. $8.50. xii + 535 pp. + 8 plates; text ill. 1949.

This textbook is designed to meet the hematological needs of medical students and practitioners. Emphasis is placed on the clinical aspects of hematology, 16 of the 24 chapters dealing with the blood picture in various diseases. No attempt is made at scholarly comprehensiveness in the text, but each chapter is followed by a short bibliography. In all respects this volume is a routine publication, quite undistinguished, but without cardinal faults. Its usefulness beyond its stated purpose is limited.

F. N. LOW

L'HÉMATOLOGIE. *Clinique et Laboratoire. Third Edition.*

By P.-Émile Weil. Masson et Cie., Paris. 1100 fr. (paper). iv + 273 pp. + 12 plates; text ill. 1949.

This primarily clinical work is divided into two parts, the first covering laboratory techniques, and the second, hematological findings in the clinic. The text is well organized and quite complete, including for example a section on the cytology of the serous cavities. The second part is organized mainly about the findings in various hematologic diseases. In the preface to this part, the author warns against only partial examination of the hematologic picture in the presence of any blood disease, and the following text therefore includes very complete clinical pictures, including many features often omitted in routine diagnosis. The style of this work is clear and its organization good. The color plates suffer from a deficiency that is very common, good distinction of relative hues but poor absolute color. The bibliography is quite sparse. This is a well written, routine account of laboratory techniques and clinical findings in hematology. It should be useful wherever French language texts are preferred. Comparable texts in other languages are not hard to find.

F. N. LOW

NERVOUS AND NEUROHUMORAL REGULATION OF INTESTINAL MOTILITY. *Monographs in the Physiological Sciences.*

By W. B. Youmans. Interscience Publishers, New York and London. $4.75. x + 129 pp.; ill. 1949.

For workers in the physiology of the alimentary tract, this little monograph will serve as a handy reference. It is essentially a review of the literature relating to certain problems and questions to be answered in this field, and covers such topics as methods of recording intestinal motility, intestinal innervation, the roles of adrenin and acetylcholine, and reflexes. This reviewer would have been more favorably impressed by something less of a lecture outline style, something more of critical comment, and the inclusion of certain references omitted in the bibliography. The author would have rendered a considerable service to his readers by closing with a chapter summarizing the parts played by nervous impulses and neurohormones in the regulation of intestinal motility, and perhaps by including some discussion of the interrelationships of these factors with emotional ones in disturbances of the alimentary tract.

R. G. GRENELL

MALADIES DU SQUELETTE.

By Lucien Leger, R. Ducroquet, and Henry Leger.

Masson & Cie., Paris. 1200 fr. iv + 255 pp.; ill. 1949.

This is a book whose interest is almost entirely clinical. It groups 8 studies of poorly recognized skeletal afflictions, now reputedly rare. Included are Albright's syndrome, osseous xanthomatosis, eosinophilic granuloma of bone, osseous neurofibromatosis (Recklinghausen), melorheostosis, Milkman's disease, essential osteolysis, and myeloma. It is excellently illustrated throughout, and adequate bibliographies are appended. The style is not difficult. Even single essays on rare diseases are noteworthy and a well-assembled collection of 8 of them especially so. It is regrettable that this fine book will have such restricted usefulness out of its special field.

F. N. Low

Histopathology of the Skin.

By Walter F. Lever. J. B. Lippincott Co., Philadelphia, London, and Montreal. $10.00. xvi + 449 pp. + 4 plates; text ill. 1949.

Lever has presented the dermatologists and pathologists with a concise textbook on the pathology of the skin. It includes over 200 photomicrographs, most of which are excellent. At the end of each chapter there are brief, but adequate bibliographies on the subjects presented.

The text contains relatively few mistakes or errors. The principal criticism of the book is the fact that the author has presented, at some length, his own theory as to the origin of epithelial tumors. It might have been preferable merely to cite the author's publications on this, and to leave out of the textbook the controversial viewpoint, at least until it is more widely accepted.

The author seems to be a little confused concerning the inclusion bodies found in the virus diseases, herpes zoster, herpes simplex, varicella, and variola; or perhaps he has attempted to oversimplify their morphology.

Lever's textbook on the *Histopathology of the Skin* is an excellent summary of the more common and most of the less common skin diseases. This makes it valuable as a reference book and for teaching students in dermatology.

Francis A. Ellis

Female Sex Endocrinology. *Concise Therapy.*

By Charles H. Birnberg. J. B. Lippincott Co., Philadelphia, London, and Montreal. $4.00. viii + 134 pp. + 3 plates; text ill. 1949.

This book is the outgrowth of a series of lectures given by the author in his postgraduate course on sex endocrinology. According to the Foreword, "it is not meant to be a comprehensive treatise and does not include discussion of controversial material or a bibliography." These limitations make criticism of it very difficult. The book reflects one man's view of the field without much consideration of current thought. The style lacks clarity. Many statements are of the following type: "Using the method of Zondek, the mature woman excretes no gonadotropins except at the time of ovulation." The best feature of the book is the collection of 30 excellent illustrations, especially the color pictures of vaginal smears. One is reluctant, however, to recommend a book which gives so little of the biochemical background of this area of endocrinology, and which offers the reader so little help in gathering further information.

Walter Fleischmann

Studies in Lobotomy.

Edited by Milton Greenblatt, Robert Arnot, and Harry C. Solomon. Grune & Stratton, New York. $10.00. xii + 495 pp.; ill. 1950.

This study, carried on at the Boston Psychopathic Hospital, is concerned with the evaluation of over 500 patients who received bilateral prefrontal lobotomy performed by a standardized neurosurgical technique. The first 205 cases were followed up for 1 to 4 years postoperatively. In an attempt to give a comprehensive picture of the lobotomized patient, the 30 contributors to this study left hardly a stone unturned. There are 24 chapters and a summary, and each chapter deals with some separate aspect of the problem. The topics considered range from the practical matters of nursing care and cerebral spinal fluid findings in the postoperative period to the eventual community adjustment of the patients. Aside from these clinical considerations, there are 12 chapters given over to special studies, such as the effect of lobotomy on various autonomic functions and the possible significance of EEG data in the pre- and post-operative periods. With regard to the central problem of the efficacy of the procedure from the psychiatric standpoint, the editors conclude that in patients properly selected (and they have something to say about how to select them), lobotomy is a feasible therapeutic tool.

Robert A. McCleary

Textbook of Virology *for Students and Practitioners of Medicine.*

By A. J. Rhodes and C. E. van Rooyen. Thomas Nelson & Sons, Edinburgh, New York, and Toronto. $5.00. viii + 312 pp.; ill. 1949.

As indicated in the subtitle and preface, this textbook is designed primarily for students of medicine, and for practitioners who desire a concise report of present knowledge in this field. It is well organized and lucidly

written, and presents in brief form essential information concerning the viral and rickettsial infections of man.

The introductory chapter, The Present Economic Importance of Virus and Rickettsial Infections of Man and Animals, is a brief but enlightening essay on the important problems in this field of study at the present time, with particular reference to the new disease entities or agents that have come to light in the last 10 years. The next 8 chapters treat various aspects of the subject from a general point of view, including 30 pages devoted to the technical methods used in studying these agents. The remaining 32 chapters are devoted to discussions of the various diseases and their etiologic agents, and is arranged mainly by natural groups based upon the organs or tissues attacked. Reflecting the interest of the medical man, the material on each disease is presented in sections set off by centered headings which in the typical case are: clinical features, pathology, epidemiology, properties of the virus, immunity, and laboratory diagnosis. This sequence is often modified to allow for desirable variation in emphasis.

The illustrations are excellent, especially those showing various exanthemata. A few more illustrations, depicting pathologic changes in infected tissues, could have been profitably included.

No citations of the published literature are included. The authors indicate that such references are available in their larger book, *Virus Diseases of Man*, (2nd edition, 1948; see *Q. R. B.*, 25: 112. 1950). The latter work, because of its encyclopedic nature, admirably supplements the present one. However, the reader will not always have that work or others at hand, and the inquiring student, at the level at which this book is aimed, would have welcomed suggested references to reviews or other sources of more detailed information on topics that capture his interest.

The writers have done an excellent job of condensing a large amount of information between the covers of a small book. In spite of the brevity of the material given on each topic, the discussions in general are up to date and include the important established facts. This brevity has resulted, however, in certain omissions that detract from the value of the book, especially for those to whom it is addressed. The absence of references has already been noted. The historical perspective has in large part been omitted, and indications of the controversial nature of discoveries at the advancing front of our knowledge are minimal. This is a mistake, in my opinion, when the intended reader is at the level of the medical or other graduate student. Those who have worked with medical students will realize that the introduction of historical perspective and an indication of the existence of controversy concerning the interpretation of observations is often at variance with the student's desires. These are nevertheless important portions of the instruction given on any specific topic. This criticism, it will be seen, does not apply so much to the book as written as to the decision to cover such a broad subject in so few pages. The shortcoming can of course be met in large part by supplementary reading. On the other hand, a concise presentation of the essential facts concerning certain human diseases is extremely useful to a large number of people representing a wide range of interests. The book will be found to be a valuable source of information not only for practitioners and students of medicine but also for students of bacteriology and other microbiological sciences, veterinary medicine (although diseases exclusively of animals are not included), for public health officers, epidemiologists, social workers, nurses, and others.

FRANCIS B. GORDON

DIANETICS. *The Modern Science of Mental Health. A Handbook of Dianetic Therapy.*
By L. Ron Hubbard; introduction by J. A. Winter. Hermitage House, New York. $4.00. xviii + 452 pp. 1950.

This is a preposterous, presumptive, pretentious book that does not deserve the serious attention being given it—even in this notice. A perversion of science, because it offers nostrums for knowledge, it must be regarded as more vicious in its effects than the astronomical romances of Velikovsky and the Scully fantasies on flying saucers. In conception, it seems to have been sired by Cybernetics out of Psychoanalysis: in execution, the author betrays that he knows little—and understands less—of either.

The fact that this absurd mixture of dressed-up half-truths and bad science has achieved the status of a best-seller, that lines actually form before the doors of so-called Dianetic "auditors," and that it has become a topic for smart conversation, reflects something more than the gullibility of the public. It is a glaring indictment of the medical profession for its failure to meet the crying need for psychotherapy in this nation. So long as the training of more and better psychiatrists is neglected, so long as the medical fraternity maintains its dog-in-the-manger attitude and refuses to admit qualified psychologists and non-medical psychotherapists to practice—just so long will such abortions and monstrosities of theory and practice as Dianetics attract an audience.

ROBERT LINDNER

PSYCHOLOGY AND ANIMAL BEHAVIOR

ANNUAL REVIEW OF PSYCHOLOGY. *Volume I. Editor: Calvin P. Stone; Associate Editor: Donald W. Taylor; 19 contributors. Annual Reviews, Stanford, Cal.* $6.00. x + 330 pp. 1950.

This volume marks the introduction of a welcome addition to the family of *Annual Reviews*. It contains 18 chapters, many of which should be of interest to biologists. Authors and their contributions are: Growth, Development, and Decline (H. E. Jones and N. Bayley); Learning (A. W. Melton); Vision (N. R. Bartlett); Hearing (E. B. Newman); Somethesis and the Chemical Senses (F. A. Geldard); Individual Differences (R. L. Thorndike); Personality (R. R. Sears); Social Psychology and Group Processes (J. S. Bruner); Industrial Psychology (C. L. Shartle); Animal and Physiological Psychology (D. O. Hebb); Abnormalities of Behavior (N. A. Cameron); Clinical Methods: Psychodiagnostics (H. F. Hunt); Clinical Methods: Psychotherapy (W. U. Snyder); Educational Psychology (L. J. Cronbach); Counseling Methods: Diagnostics (R. F. Berdie); Counseling Methods: Therapy (E. S. Bordin); Statistical Theory and Research Design (D. A. Grant); and Problem Solving and Symbolic Processes (D. M. Johnson).

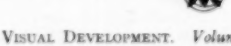
A. CHAPANIS

HABITS. *Their Making and Unmaking.*

By Knight Dunlap; introduction by H. M. Johnson; selected bibliography and evaluation of recent developments in habit formation by Joseph E. Morsh. Liveright Publishing Co., New York. $3.00. xvi + 394 pp. 1949.

Knight Dunlap was always somewhat of an iconoclast, and in 1932 he published a book, *Habits: Their Making and Unmaking*, which attacked directly several psychological notions about learning, habits, and intelligence. It was in this book that he formulated his famous rule that to break a habit one should practice it assiduously. He had several other novel things to say about contemporary psychological theories, and these are still worthwhile reading for students of psychology. The present volume is a reprint of the 1932 edition. The bibliography, however, has been enlarged and brought up to date by Joseph E. Morsh.

A. CHAPANIS



VISUAL DEVELOPMENT. *Volume I.*

By J. H. Prince; with a foreword by Professor H. Hartridge. Williams & Wilkins Co., Baltimore (printed in Great Britain). $9.50. xii + 418 pp. 1949.

This is a curious sort of book, and it is difficult to describe exactly what it is about. The author describes the area he writes about as "ocular naturalism" or "zoological optica," but it would probably be most nearly correct to say that it is a kind of comparative psychophysiology of vision. Part of the difficulty one encounters in trying to describe the contents of the book arises from the diversity of the material in it—more about which in a moment.

The author has apparently traveled widely, studying and collecting animals and observing them in their natural habitats and in zoos. In part, this volume is an attempt to summarize the kinds of eye structures and visual behavior he found. Part I of the book discusses essentially introductory material: perception, retinal structures in man and animals, and photochemistry. Part II is concerned with the evolutionary development and comparative physiology of vision. Part III deals with color vision and its evolution in man and animals. Part IV is strangely out of place. It takes up night vision and dark adaptation in man, night blindness, and night vision tests. Apparently this material comes from the author's doctoral investigation, and he just could not resist putting it into the present volume. Part V is essentially methodological, since it is primarily concerned with techniques for examining the eyes of animals in vivo and for preparing histological specimens.

There is much of value in this book for the student of biology and vision. One might wish that the contents were better organized and selected, but the inherent interest of some of the material may compensate for the book's other deficiencies.

A. CHAPANIS

SIGHT, LIGHT AND EFFICIENCY.

By H. C. Weston. H. K. Lewis & Co., London. £2. 2s. xiv + 308 pp. + 11 plates; text ill. 1949.

This book is an elementary discussion of vision, visual skills, industrial lighting, and illuminating engineering. There are 8 chapters dealing with the sense of sight, the causes and symptoms of eyestrain, occupational demands upon sight, the facilitation of visual tasks, lighting and visual efficiency, light and color for work spaces, visual tests, and ways of protecting the eyes from industrial accidents.

Although the book was written from a practical standpoint, the author has discussed basic data in enough detail for the reader to get a reasonable look at the experimental backgrounds of these subjects. There are 132 good illustrations, many of which have been ingeniously devised to portray complex information in an effective manner. An appendix gives recommended illumination values for over 200 tasks and work areas. The visual scientist will, of course, find this material elementary, and even skimpy, but applied scientists, engineers, and industrial psychologists should find the book a welcome addition to their libraries.

A. CHAPANIS

INDIVIDUAL BEHAVIOR. *A New Frame of Reference for Psychology.*

By Donald Syngg and Arthur W. Combs. Harper & Bros., New York. $3.50. x + 386 pp.; ill. 1949.

This frame of reference which shifts the field of observation from the experience of the observer to the experience of the behaver is not new, but in the treatment, well-reasoned and full of insight, given it by these writers it has attained its most convincing formulation thus far. The essential thesis of Syngg and Combs is that all behavior is determined by the present phenomenal field of the behaving organism. It is, accordingly, not the *situation*, but rather the way in which the behaving organism perceives it that determines behavior.

Persistent topics of psychological interest are examined in the light of this approach. Point after point is cogently scored so as to show the dead ends into which conventionally objective approaches have led us in the search for prediction and control of human behavior. Our investigations have traditionally had two questionable results. First, they have tended to limit our knowledge to central tendencies of the average, or normative, individual. Second, they have become identified and confused with the object of our study, namely, human behavior itself. Within this framework the authors attempt to correct these deficiencies by making psychological knowledge more concrete and particular, on the one hand, and by rescuing the reality of human behavior from the unreality of the conventional methods of objective study, on the other.

This pioneer work should be carefully read by all who believe that in psychology as science our goal is to know how a particular individual in a unique situation will behave. Although the authors have not, as we might expect, specified the answer, they have successfully posed the problem and indicated the direction in which research must move if it is eventually to prove fruitful.

JOSEPH C. FRANKLIN

CHILD GROWTH AND DEVELOPMENT.

By Elizabeth B. Hurlock. Whittlesey House, McGraw-Hill Book Co., New York, London, and Toronto. $3.50. x + 374 pp.; ill. 1949.

Here is another book written to acquaint young parents with what they should know. The author in her Introduction recognizes that hers is only one of many such volumes to be turned out in recent years. It is her hope, however, that in this book she can offer something different. The difference, she feels, is in the scope of the book and in the fact that her knowledge is not only theoretical, but practical, since she, herself, has been a mother. There is no question that this latter experience makes her a more valuable person to report on the subject of what raising a family really means.

Dr. Hurlock does indeed manage to cover a multitude of topics. The book is divided into four parts: (1) how life begins; (2) the child's growth; (3) the child's problems and habits; and (4) the child as a person. To a sophisticated reader the details she includes are extremely elementary, but for the average young parent, I am sure it would be reassuring to have the simplest details gone over in simple language.

The book itself is quite attractive. The print is large and well-spaced and the inclusion of frequent excellent photographs to illustrate the material makes it unusually pleasant and easy to read.

HELEN ARTHUR

MODERN DISCOVERIES IN MEDICAL PSYCHOLOGY. *Second Edition.*

By Clifford Allen. Macmillan & Co., London. $2.00. xii + 236 pp. 1949.

This book first appeared in 1937. The subject-matter of the ten chapters will indicate its contents: Mesmer and Hypnosis; Janet; Morton Prince; Freud and Other Psychoanalysts; Adler; Jung; Kretschmer; Pavlov; Wagner-Jauregg. The book is very well written, gives a great deal of historical background, important for understanding present-day psychiatry, and appears quite eclectic and conservative. There are interesting tidbits of information, such as the note that "Mesmer was responsible for launching Mozart as an established musician." (I wonder where the author found out this fact. I have never run across it in any of the several biographies of Mozart that I have read.)

As a short introduction to the history of psychiatry and a summary of the important contributions from the various fields of our present-day methods, this book is very good indeed. It is not surprising that it has been translated into such diverse languages as Italian and Bengali.

I find only one serious criticism to make. Allen states: "We shall return to the study of the wish which Freud found so important. Now, it must be admitted that the enemies of Freud must be careful not to admit any single part of his discoveries to be valid, since one part is interlocked with the other part, and if one admits that one thing is correct, one is forced to admit the validity of the whole edifice" (p. 79). My criticism of this rests on the use of the word "enemies." I doubt if there can be found among sober, thoughtful psychiatrists today any "enemies" of Freud, although there have been and are and will be critics. If, in fact, to admit one element in the Freudian system requires admission of the whole, then there ought to be

critics who should multiply abundantly, because only through critical contemplation of the dogmatic edifice can fact be stripped from theory and fancy. Considering Freud's own capacity for criticism, I think he would agree.

WENDELL MUNCIE

THE YEARBOOK OF PSYCHOANALYSIS. *Volume V. Managing Editor: Sandor Lorand. International Universities Press, New York.* $7.50. 317 pp. 1950.

The fifth volume of *The Yearbook of Psychoanalysis* maintains the excellent standard set in the previous volumes. It is a collection of 22 papers of real worth. The fact that the majority of these papers include dynamic, clinical orientations makes this collection particularly useful for the student in this field.

The introductory paper, Symposium on the Evaluation of Therapeutic Results (Oberndorf, Greenacre, and Kubie) seems a very important addition to the *Yearbook*. To have three psychoanalysts of such stature discuss with energy and honesty so difficult a subject as the genuine evaluation of the results of psychoanalytic treatment, is fascinating indeed. There cannot, of course, be a definitive treatment of this vast subject, but there is agreement that an adequate survey is important, and the character of such a survey is formulated.

Nunberg, in a paper entitled Problems of Therapy, has probed many of the factors that influence the progress or discouragement in psychoanalytic treatment. Berta Bornstein has written an exceedingly interesting report on emotional factors in the psychoanalyst that interfere with the understanding and treatment of children. This is related specifically, of course, to psychoanalysts of children, but one might also draw conclusions or inferences about similar limitations in working with adult patients. There are a number of papers on different aspects of dreams. There are also papers by Franz Alexander, Karl Abraham, and Anna Freud, to mention a few of the most highly respected names in psychoanalytic circles.

This is only a very general survey of the book, but it would be impertinent really to attempt more than to point out that each of these papers is worth reading in detail and in entirety. The book belongs with its predecessors in every psychoanalyst's library.

HELEN ARTHUR

ADVENTURES IN THE SUPERNORMAL. *A Personal Memoir. By Eileen J. Garrett. Creative Age Press, New York.* $3.50. x + 252 pp. 1949.

This book is an autobiographical sketch of a woman's adventure with what she calls her "psychic" gift. Her experience began in childhood when she found it expedient to "withdraw from the world and live within myself," the reasons given for this need being a harsh aunt, mother surrogate, with whom she lived. "I could voluntarily shut away the sound and the sense of her harshness, and by closing my eyes I could cancel out her very existence and live in a hidden place within myself where nothing could intrude." She goes on to describe her lonely and "strange" childhood in which "I had my secret companions, two girls and a boy" whom she calls "the children." These fantasy characters entered her life at the age of 4 and she communicated with them "but without words." They were the only unchanging aspects of her early environment and they "taught me not to regard too seriously everything that grownups said." These "children" taught the author to observe carefully the meanings of "tones" and "cadences" in peoples' voices and to interpret facial expressions, such that by the time the author entered school "I had come to know that human beings never quite speak the truth." At the time she conceived of "the children" she was a lonely child without playmates, and was treated by her aunt as an "unruly child given to falsehood and disobedience." However, even after starting school, the author felt herself "apart in temperament and spirit from the children of my own age." These children "accepted the authority of grownups but theirs was only a pretense of submission." It was at this point of her life that our author began to believe "that I saw people, not merely as physical bodies, but as if each were set within a nebulous egg shaped covering of his own." By observing this nebulous covering she could interpret changes in peoples' moods, and she began to pay more attention to this phenomenon than to the actual person surrounded by it.

The author was the product of a tragic marriage between her mother and a foreigner of different faith who forbid her to communicate with her own family. When the mother became pregnant, she asked to return home to her parents, but was refused and instead was received by the aunt with whom our author later lived. Because this aunt could not bear the foreign husband in the house, he took his wife to a nearby cottage, where they lived in unhappiness until just after the child was born. The mother then drowned herself in despair over her family's rejection, and was followed 6 weeks later by the suicide of the father, leaving the child to be raised by the strict aunt and a rather passive, yet friendly uncle. This information was not given the author until she was in her early teens, at which time her reaction was to feel so deeply the "injustice and intolerance of the family" that in her dejected state she once again attempted to recapture her earlier and more secure relationship to "the children," although now with only partial success. Shortly after this the author had her second physical breakdown, through active tuberculosis, and left her native Ireland and her aunt for England.

The author regained her health and married in London and again experienced tragedy because she was unable to accept any master, and a struggle for independence ensued with her husband. She bore three children, all of whom died early in life. She then tried to interest herself in social services, musical comedy, etc., and again was unsuccessful in attempting to free herself from "the industrial and economic bondage that a house and husband represented to me." In her idleness she turned to the "inner world" which offered more gratification than real life experiences. She began to experience "supernormal sensing" of a deep intensity. She found herself "seeing more easily and clearly through my fingertips and the nape of my neck than through my eyes, and hearing and knowing, for instance, came through my feet and knees."

It was in such a setting and background that the author became active in groups dealing with psychic phenomena such as psychometry, clairvoyance, clairaudience, and telepathy. The remainder of her book deals with her personal experiences in these fields of psychic research, both in England and America, including a visit to the laboratories of Rhine at Duke University. Her experiences are interesting and well described, although one cannot always agree with her conclusions on the basis of the evidence given.

ARTHUR HANSON

THE BIOLOGY OF MENTAL DEFECT.

By Lionel S. Penrose, with a preface by J. B. S. Haldane. Grune & Stratton, New York. $4.75. xiv + 285 pp. + 7 plates; text ill. 1949.

L. S. Penrose, whose writings have always been distinguished for their clarity, thoroughness, and penetration, has now provided us with an excellent volume on mental deficiency from the standpoint of human biology. While the core of the volume is human genetics, the discussions probe deeply into the medical, psychological, and sociological aspects of mental defect.

Following a very readable account of the history of the problem, the measurement of intelligence is discussed, leading to clear definitions of the types of defectives and the incidences of the various classifications. The principles of classification are carefully delineated.

An important chapter is devoted to the principles of causation, in which environmental influences and the various types of gene substitutions are described, with a thorough assay of methods for distinguishing between them. It is pointed out that irregular modes of transmission are highly characteristic of human genetics, and that this may well be due to the large number of biophysical or biochemical steps occurring between the genes and their final manifestations in many human anomalies and aberrations. The many intervening steps permit the ready modification of traits by the actions of other genes, by the environment, and even by unpredictable chance circumstances.

The problem of anticipation is discussed. The suggested explanations of apparent instances are very much to the point, and should serve to minimize the prominent role often attributed to this apparent, though probably not real, phenomenon.

Methods of analysis in human genetics are thoroughly described in a chapter of fundamental importance. This is followed by the detailed discussion of the genetics of intelligence and of individeal mental disorders. Particular attention is paid to rare traits, both autosomal and sex-linked. Not only genetic analyses, but clinical descriptions, legal aspects, and treatment are carefully outlined for each mental condition. A 24-page bibliography and 10 useful tabular appendices complete the volume. Penrose's very fine treatise should be required reading for all those who in any capacity are associated with or are interested in those human individuals who suffer from mental defect of any sort.

LAURENCE H. SNYDER

CURRENT TRENDS IN INDUSTRIAL PSYCHOLOGY. *Eight lectures under the auspices of the Department of Psychology in The College of the University of Pittsburgh delivered during February 18 and 19, 1949 in the Stephen Collins Foster Memorial.*

By Wayne Dennis, Carroll L. Shartle, John C. Flanagan, Orlo L. Crissey, William McGehee, Brent Baxter, Daniel Katz, and Harold C. Taylor. University of Pittsburgh Press, Pittsburgh. $3.75. 198 pp. 1949.

The lecturers and their 8 topics are as follows: The Background of Industrial Psychology (Wayne Dennis); Organization Structure (Carroll L. Shartle); Job Requirements (John C. Flanagan); Personnel Selection (Orlo L. Crissey); Training in Industry (William McGehee); Employee-Management Relations (Brent Baxter); Morale and Motivation in Industry (Daniel Katz); and Industrial Psychology and the Community (Harold C. Taylor). This is an informative and well balanced survey for the reader who is interested in this phase of contemporary psychology.

A. CHAPANIS

INDUSTRIAL PSYCHOLOGY AND ITS SOCIAL FOUNDATIONS.

By Milton L. Blum. Harper & Bros., New York. $4.50. xiv + 518 pp.; ill. 1949.

This is a new orientation and approach in the writing of textbooks of industrial psychology. The author holds that industrial psychology "must boldly expound the view that democratic principles must be applied to

industry" and must, moreover, reckon with "the tremendous importance of the worker as an integrated social being."

It is because he holds this point of view that Blum's chapters dealing with job satisfaction, industrial morale, work environment, leadership, industrial warfare, and unemployment give a realistic treatment of issues which most textbooks in this field ignore or treat glibly. All in all, his book is a well-balanced, level-headed addition to any student's purview of the issues and the controversies they have aroused, matters which no introduction to this field can any longer honestly bypass. It is to the author's credit that he has fairly presented various points of view on conflicting and controversial points—of which there are many—and yet, in so doing, has augmented the plausibility of his own analyses. Although some may find his treatment of traditional topics, such as vision, job selection, testing procedures, and the like, too brief, there is no question but that in the larger sense Blum has given us a treatment of the subject which does provide considerable understanding of those social bases of industrial psychology which he deems necessary "if the promotion of more harmonious employer-employee relations in a democratic society is to be given realism and meaning."

JOSEPH C. FRANKLIN

SELECTED READINGS IN SOCIAL PSYCHOLOGY.

Edited by Steuart Henderson Britt. Rinehart & Co., New York and Toronto. $2.00 (paper). xvi + 507 pp. 1950.

This paper-bound book should adequately fulfil its announced purpose of providing an inexpensive collection of supplementary readings for the undergraduate course in social psychology. It contains 50 selections covering major topics of Methods, Biological and Social Foundations of Behavior, Individual Factors of Social Adjustment, Behavior in the Presence of Others, Social Psychology of Institutions, and Social Conflicts. On each of these topics there are at least several articles. Major emphasis in choosing the papers was placed on experimental and observational reports, brief selections being used rather than digests or summaries of longer articles or books. This collection appears well selected to illustrate the important current thought in the area of social psychology and the methods used in social research. The student should find the articles of sufficient current importance to sustain his interest and to encourage further reading. The book is provided with a single alphabetical index, and as an additional aid to the instructor and student the subject matter of each article in the book is collated by page numbers with the contents of 11 currently used textbooks of social psychology.

H. J. BOND

HUMAN BIOLOGY

HUMAN BIOLOGY. *Second Edition.*

By George Alfred Baitsell. McGraw-Hill Book Co., New York, Toronto, and London. $6.00. xviii + 730 pp.; ill. 1950.

The second edition of this well-known text (*Q. R. B.*, 15: 476, 1940) has been revised, "brought up to date," and contains many new illustrations. As the title implies, man is the biological organism used primarily to illustrate the various principles of anatomy, physiology, development, and heredity. Animals and plants are mentioned only when pertinent to some particular topic. One chapter is entitled The Biotic Environment, but in reality it discusses only interspecific relationships, such as symbiosis and parasitism, and animal societies, but omits any discussion of adaptations or the effects of the physical environment. Human racial crosses are apparently discouraged on the basis that the F_2 generations show inferior qualities; criminal tendencies are suggested as being definitely inherited on the basis of fraternal vs. identical twin records. Topics of this nature should be treated with more caution. Evolution receives treatment only in the Appendix. This Appendix, incidentally, is a rather unique feature of the book, being long (pp. 537–689) and containing considerable additional information on various topics supplementing the text and ranging from "abiogenesis" to "X rays." This material has been quoted verbatim from original sources. Students who enter college with some previous training in biology will find this emphasis on man to be of greater interest, and for them this is an excellent textbook.

HENRI C. SEIBERT

VITAL FACTS OF LIFE. *A Christian View of Sex and Life.*

By Carl H. Harman and E. W. Marquardt. Concordia Publishing House, Saint Louis. $1.75. xvi + 126 pp.; ill. 1949.

As the title indicates, this is a religious rather than a scientific treatment of sex and marriage. It is "a product of many case histories of a doctor and a minister." It aims to help parents and young men and women, as well as "ministers, teachers, school administrators, summer camp leaders, in fact, all youth workers" to "pave the way to a happier, better adjusted adulthood—and marriage."

As is to be expected, this book abounds in teleology: "the tear glands give off moisture to keep the eyeballs clean and healthy" and "the liver . . . secretes bile . . . to help in the digestion and assimilation of food," etc. To what extent such constantly recurring unscientific phrases as ". . . the sex instinct, with which God endowed man for the high purpose of propagating the human race" or "the unborn child—nourished through the navel" can really help young persons to solve their

pressing problems during puberty and later, one may only wonder. It would seem that any book of this type should adhere rigidly to scientific accuracy, if for no other reason than that young persons today, once they detect such lack of accuracy, are likely to discredit the rest of the context. The great importance of the aims of this book would seem to demand a greater care for "vital facts of life" than is discovered in its pages.

ELLA THEA SMITH

IS SEX NECESSARY? *"Coming of Age" Edition.*

By James Thurber and E. B. White, with a new introduction by E. B. White; illustrated with the original drawings by James Thurber. Harper & Bros. New York. $2.75. 190 pp.; ill. 1950.

The discovery that the only copy of this treatise in the libraries of The Johns Hopkins University is carefully preserved in the Institute of the History of Medicine has compelled the editor to regard the new edition as worthy of some lines in the *Quarterly Review of Biology*. He has turned to me as an expert on the subject. After making a careful study of this engrossing subject and after collation—a useful word I have picked up through my association with the editor—of this with the first edition, I find I am considerably disappointed. Clearly, the 25 years since Thurber and White wrote this exhausting treatise have brought them and their authorities no closer to an answer. In fact, they show certain faint signs of distaste for the whole subject. Can it be that Thurber and White are growing old?

PERCY, THE OFFICE BOY

THE SCIENCE OF CULTURE. *A Study of Man and Civilization.*

By Leslie A. White. Farrar, Straus & Co., New York. $6.00. xx + 444 pp. 1949.

We have often complained in this journal about the psychological aberrations of contemporary cultural anthropologists. We must on the other hand admit that the "culturological" medicine offered by White against this disease seems of little help.

According to White, everything is very simple. "Culture" controls man. Free will is a delusion. "Culture" depends on technology. White's culturology is a somewhat clumsy reedition of Marx' historical materialism, lacking entirely the social optimism of the latter. White lives in the happy delusion that when he has stated that "culture" is the cause of something, he has explained all there is to explain. It is precisely the continuous inability of "culturology" to explain and predict that has brought about the somewhat misguided psychological excursions of contemporary anthropologists. The sterile, scholastic argumentativeness of White and such "brilliant" mannerisms as "Symbolling," "Mind is minding," "Science is sciencing," are unlikely to bring them back to more fruitful lines of endeavour.

ERWIN H. ACKERKNECHT

LAW AND GOVERNMENT OF THE GRAND RIVER IROQUOIS. *Viking Fund Publications in Anthropology, Number Twelve.*

By John A. Noon. Viking Fund, New York. $2.00 (paper). 186 pp. 1949.

Studies of law and government among preliterate peoples are fundamental to the success of proposed programs for the development of economically underdeveloped areas. The experience of dealing with tribal governments in North America goes back three hundred years, and quite as long in Africa. British colonial administrators have always been adept at adjusting policy to native political systems, and quite consistently the Colonial Office has encouraged the research of English anthropologists in Africa and Melanesia. To their American colleagues we owe a growing series of studies of law and government among North American Indians, and the U. S. Government has cooperated in much of this research. The Grand River Iroquois are the descendants of Loyalist Indians who fled to Canada after the Revolution. John A. Noon, who is now with the Africa Branch of the Department of State, visited the Grand River in the summer of 1941 as a graduate student from the University of Pennsylvania. He surveyed the records of the Indian Office in Brantford and the Minutes of Council at Ohsweken, and employed as informants old councillors. From these sources he assembled a casebook of Iroquois law, the data for the present study.

Limitation of sources made it impossible to reconstruct early Iroquois law, but Noon did discover and has revealed here the amazing skill with which these Indians used the powers of government to adapt their ancient political forms to a new pattern of society and to adapt traditional council procedures to judicial purposes. The Grand River Iroquois had reconstructed their ancient League in Canada. Noon explains how what had originally been a defensive confederation became the mechanism of local government. The focus of social control shifted from areas of intertribal affairs to relations with the Dominion government, from the treatment of captives to sanctioning behavior of tribal members, from hunting to control of natural resources, from land cessions to settling boundary disputes between tribal members. Three premises underlie Noon's theory of the Iroquois legal system: the all-inclusive nature of rules; their transcendency; and their tend-

ency to develop during a crisis. Chapters treat severally the appointive and legislative powers of the council, the development of constitutional law through judicial decision, the social control of citizenship, property and inheritance, and the coordination of society.

Biologists destined to work on public health problems in underdeveloped areas should get acquainted with such literature before going to the field and before making recommendations which will affect native society.

WILLIAM N. FENTON

MIDWINTER RITES OF THE CAYUGA LONG HOUSE.

By Frank G. Speck, in collaboration with Alexander General (Deskaheh). University of Pennsylvania Press, Philadelphia. $4.00. xiv + 192 pp. + 16 plates; text ill. 1949.

It is significant that Frank G. Speck's final and most important ethnological work should center on the problem of local diversity in the culture of Iroquoian-speaking Indians of the eastern United States and Canada. The present work is the culmination of a career spent in snatching dying echoes of culture from surviving Indian groups between Alabama and Labrador. The Cayuga are one of the Six Nations of New York, now living in Canada, where they maintain a yearly cycle of agricultural festivals. After 1931, Speck went to Grand River every winter to work with Chief General, completing his book in 1939, and adding few sections later. Part One concerns the religious framework of Cayuga culture; and next, the organization of officials, foods, and paraphernalia. Part Two gives in detail the Midwinter Ceremony proper. Subsequent sections are devoted to the analysis of specific rites and dances according to form and function. The book is overbalanced because of intense observation at one season, with a thin description of rites scattered over the year and which is was not feasible to witness. Transcriptions of recorded music were not available for publication. The book is illustrated, indexed, and contains a bibliography. It is an important contribution to American ethnography.

WILLIAM N. FENTON

UTE PEYOTISM. *A Study of a Cultural Complex. Univ. Colo. Stud., Ser. Anthropol., No. 1.*

By Omer C. Stewart. University of Colorado Press, Boulder. 50 cents (paper). ii + 42 pp. + 1 plate; text ill. 1948.

O. C. Stewart, whose excellent monograph on *Washo-Northern Paiute Peyotism* has been reviewed previously (*Q. R. B.*, 19: 356. 1944), in this new monograph adds descriptive material to his study of Peyotism. He gives a general interpretation of Peyotism that differs considerably from the previous ones by Radin and others, but has many very suggestive elements. The remarkable uniformity of the peyote cult over a large distribution area suggests that it was diffused as one complex rather than that the peyote and Christian traits were grafted upon local Indian religions. Stewart deems it possible that the complex was elaborated in Northern Mexico around 1770, that is, more than a century before its first description by ethnographers.

ERWIN H. ACKERKNECHT

A VILLAGE THAT CHOSE PROGRESS. *Chan Kom Revisited. Social anthropol. Ser., Univ. Chicago Pub. Anthropol.*

By Robert Redfield. University of Chicago Press, Chicago. $2.75. xiv + 187 pp. 1950.

In southeastern Yucatan, late in the 19th century, Indians began cultivating corn fields (milpas) and building wattle and thatch houses at a place known as Chan Kom. The place had little to recommend it aside from its natural well. Nevertheless, within a lifetime Chan Kom has grown from an unorganized collection of milpas and houses under the jurisidiction of the parent community to an independent, Spanish-type town, heading a *municipio*. This transformation was due mainly to unusual leadership on the part of some early settlers.

The leaders used the idea of attaining the status of *municipio* as an incentive for community advancement. Soon after the attainment of this goal, the depletion of the soil forced the inhabitants to turn to commerce. As a result of these changes, the town was exposed to cultural influences from the non-Indian world. Now, with no new goal, the older leaders going, the new generation giving up the old customs, and the population increasing, Chan Kom is facing a crisis.

The biography of Chan Kom is available only because the Carnegie Institution of Washington in the 30's planned a broad study of the Maya Indians. The proximity to Chan Kom of the famous ruins of Chichén Itzá brought the village school teacher, Sr. Alfonso Villa Rojas (now a noted anthropologist) into contact with the North Americans. In 1931 Redfield and Villa Rojas published their first study. In 1948 Redfield revisited the community, and the present readable book is the result. "Chan Kom seems to tell us something about civilization . . . and some of its discontents, that is relevent elsewhere."

T. D. STEWART

THE PRE-HISTORY OF THE LAGOA SANTA REGION, MINAS GERAIS.

By H. V. Walter. Alfred Wilson, London; distrib-

uted by Cadmus Book Shop, New York. $4.50 (paper). xii + 167 pp. + 71 plates. 1948.

This small volume is written in Portuguese and English, the two languages being placed on facing pages. How helpful this is! Anyone with a background in any Romance language could use this as a pleasant aid to a reading knowledge of Portuguese.

The Lagoa Santa region is of interest to paleontologists and anthropologists because of its great limestone caves. One hundred years ago Lund, a Swedish naturalist, explored these caves. His collection of Pleistocene fossils is one of the great sources of knowledge of the life forms of the unique South American area. Lund also opened a great controversy by reporting the presence in these caves of human skeletons in association with, and often having similar degrees of fossilization as the extinct Pleistocene fauna. The present report concerns further exploration of these caves in this century.

A brief statement describing the area and its emergence into scientific notice is given first. Short descriptions and a few illustrations of the implements of the Lagoa Santa people leave one wishing for a more adequate treatment. Geographical descriptions of the caves excavated are fair; the scanty descriptions of the excavations leave one wondering about the absence of techniques of surveying and recording. One is dealing here with "qualitative" work; all depends on the worth of the excavator. One gets an impression of honest, conscientious work.

The finding of the Confins Man and the Pedro Leopoldo Man are reported here in some detail, together with anthropometric data on the skulls. Both finds seem to belong to the long-headed, prognathic, heavy-browed men found practically universally in America under conditions suggesting Pleistocene time. Both of these finds were in such position as to suggest that they were in place with the extinct giant fauna of the region. The finding of a wooden arrow (atlatl?) shaft and point with one of the men is of special interest.

In addition to a general discussion of the extinct Pleistocene mammals of the region, there are two detailed reports. One concerns the finding of a relatively complete fossil armadillo (*Hoplophorus euphractus* Lund) in Borges Cave. The preservation of the carapace and caudal tube is particularly noteworthy in this specimen. The other paleontologic find reported in detail concerns *Arctotherium brasiliensis*, the short-faced bear.

It is of interest, as always, to note the unequal treatment of human and any other fossils. The extinct fauna is assumed to represent Pleistocene time; the men accompanying the fauna are not. It is clear, however, that the author would include man within the time of the rest of the fauna if it were not for the still powerful *opinion* that man is a Recent arrival in the New World.

GEORGE F. CARTER

EXCAVATIONS AT KAMINALJUYU, GUATEMALA. *Carnegie Institution of Washington Publication 561.*

By Alfred V. Kidder, Jesse D. Jennings, and Edwin M. Shook; with technological notes by Anna O. Shepard. Carnegie Institution of Washington, Washington, D. C. $8.00 (cloth); $7.00 (paper). x + 384 pp. + 90 plates + 1 chart; text ill. 1946.

Kaminaljuyu, an archeological site on the Pacific slope of Guatemala, was discovered only a few years ago while a football field was being graded. The wealth of material which it has brought to light, artifacts, jewelry, tombs, pyramids, etc., amply justifies the publication of such a voluminous and detailed report as this one. The authors designate the 3 major stratifications in Mesoamerica as the Middle, Classic, and Late. Of these, the Middle is the oldest and lowest. The paradoxical name has been given because the artifacts from the Middle horizon indicate a culture too highly developed to be considered primitive.

There are over 100 black and white plates and 4 in color, the latter depicting examples of the fictile art of these ancient Americans. The others depict details of architecture and masonry of the tombs, along with the skeletons disinterred from them. Some of the burials must have been of persons of distinction, to judge from the quantity and quality of the artifacts recovered from their tombs, but the majority seem to have been slaves or concubines who were executed and interred with their owners. There are apparently no signs of religious sacrificial practices similar to those to which the pre-conquest Aztecs were addicted.

A high degree of technical skill is revealed in the elaborately carved figurines of stone; polished beads; bowls of jade and alabaster; arrow points of obsidian; manos and metates essentially similar to those used today; ornaments made of shells from both oceans; carved bones, a human skull among them; tools of bone; incense burners; pottery vessels and fragments of basket ware. The book contains a folded diagram and 2 maps, a bibliography, and a table of contents, but unfortunately there is no index.

BIOMETRY

THE THEORY OF PROBABILITY. *An Inquiry into the Logical and Mathematical Foundations of the Calculus of Probability. Second Edition.*

By Hans Reichenbach; English translation by Ernest H. Hutten and Maria Reichenbach. University of California Press, Berkeley and Los Angeles. $12.50. xvi + 492 pp.; ill. 1949.

This is the first book in English to deal convincingly with the logical foundations of probability theory. Whether or not one accepts Reichenbach's views in toto, the careful and clear-cut analysis is extremely

valuable. The foggy thinking and confusion that have attended previous inquiries are conspicuous by their absence here.

The book goes far beyond its title and deals with the question of inductive inference. The role of probability in the process of inference is considered in some detail. As a consequence, this book will be useful to anyone who wants to understand the logical structure of "scientific method."

The subject is difficult, and although the author has done his best to enliven the discussion with amusing illustrations most readers will find it hard going. Some previous knowledge of symbolic logic, epistemology, semantics, mathematics, and probability theory is needed to follow the development. However, the reader who is willing to make an effort will be amply repaid.

For the first time the methodologies of modern statistics are incorporated into the inductive process. Some statisticians will not be pleased with the manner in which this is done. Bayes' Theorem is given a clean bill of health and is used to justify the method of Maximum Likelihood! It is rather interesting that Reichenbach's vindication of Bayes' Theorem should come at a time when statisticians have (for other reasons) begun to use it again.

I. J. Bross

Sampling Methods for Censuses and Surveys. *By Frank Yates. Hafner Publishing Co., New York; Charles Griffin & Co., London.* $5.50. xiv + 318 pp.; ill. 1949.

This is an authoritative and well-written work on sampling methods. The author, a statistician of great repute, is head of the Department of Statistics at the Rothamsted Experimental Station and a member of the United Nations Sub-Commission on Statistical Sampling.

The eight chapters of the book are headed: The Place of Sampling in Census Work; Requirements of a Sample; The Structure of Various Types of Sample; Practical Problems Arising in the Planning of a Survey; Problems Arising in the Execution and Analysis of a Survey; Estimation of the Population Values; Estimation of the Sampling Error; and Efficiency. Although the title of the book contains the word "census," the principles given in it are quite general and are easily adapted to the sampling of biological populations. In fact, most of the illustrations in the book are drawn from the author's wide background of experience in agricultural research. Experimenters will find Yates' book eminently practical since, unlike Deming's *Some Theory of Sampling* (see below), it was written for those who have little or no previous training in mathematical statistics, but who have some training or experience in the presentation and handling of statistical data.

A. Chapanis

Some Theory of Sampling. *Wiley Mathematical Statistics Series.*

By William Edwards Deming. John Wiley & Sons, New York; Chapman & Hall, London. $9.00. xviii + 602 pp. 1950.

Students, teachers, and research workers in the biological sciences now have available to them a great variety of statistics textbooks, but there are few sources to which they can turn for an adequate discussion of sampling procedures. This is unfortunate, for in some respect an understanding of proper sampling techniques is more important than an appreciation of conventional statistical formulae. The validity of any experimental result, whether or not the experimenter has used statistics, depends first of all on the adequacy of the sample used in the experiment. This is true no matter whether the experiment is concerned with trees, birds, amoebae, people, rocks, or manufactured items, like electric light bulbs, steel, or neckties.

Deming's book is a welcome addition to the literature on biometry and statistics, because, despite the modest implications of its title, it is a thoroughly adequate coverage of the problems of statistical sampling. The author is eminently well qualified to write in this area because of his broad experience in government and industry in the sampling of human populations, commerce, and physical materials. Among other things, he is Adviser in Sampling to the U. S. Bureau of the Budget and a member of the U. N. Sub-Commission on Statistical Sampling.

The book, unfortunately, is a heavy one. Even the author acknowledges that the first 13 of its 17 chapters constitute a year's study for students in the social sciences and commerce. Readers of it should already have had a course in statistics and at least a smattering of calculus. The chief value of this book will probably not be as a classroom textbook, but rather as a volume for independent study or a reference work for biometricians and mature research workers. Such people will find much of value in it.

A. Chapanis

Experimental Designs. *Wiley Mathematical Statistics Series.*

By William G. Cochran and Gertrude M. Cox. Editor: Walter A. Shewhart. John Wiley & Sons, New York; Chapman & Hall, London. $5.75. x + 454 pp. 1950.

This book is designed as a handbook for experimental workers in the fields of biology, psychology, and agriculture. As such, it should prove of considerable value. Detailed consideration is given to 150 different experimental plans based upon the analysis of variance, covariance, and latin square techniques. Each design is considered in detail, not only with respect to the plan of the experiment and the computational steps, but also in terms of the advantages and disadvantages

of the particular design. The extensiveness of the book is best conveyed by some of the individual chapter headings: Completely Randomized, Randomized Block, and Latin Square Designs; Factorial Experiments; Confounding; Factorial Experiments with Main Effects Confounded (Split Plot Designs); Factorial Experiments Confounded in Quasi-Latin Squares; Balanced and Partially Balanced Incomplete Block Designs; Lattice and Cubic Lattice Designs; Balanced and Incomplete Blocks; Lattice Squares; and Incomplete Latin Squares (Youden Squares).

The authors have assumed that the reader will have a basic understanding of the analysis of variance, and granting this, their presentation is clear and concise. Experimental workers in the biological sciences have been in need of an authoritative and handy source to assist them in selecting the more efficient plans for their experiments. This need has been admirably met by *Experimental Designs*.

CHARLES W. ERIKSEN

EXPERIMENTAL DESIGN IN PSYCHOLOGICAL RESEARCH. *By Allen L. Edwards. Rinehart & Co., New York.* $5.00. xvi + 446 pp. 1950.

This book is intended as a textbook for an intermediate course in statistics. In addition to a general discussion of some basic considerations in experimental design, the book covers χ^2, the various applications of the t-test, simple and complex factorial designs, latin squares and simple covariance. On the whole, the book is quite readable. The exposition is clear, and extensive use has been made of the experimental literature for illustrative examples.

Among the special merits of the book are its coverage of certain statistical problems that are generally considered only in journals. Edwards discusses such problems as: tests for heterogeneity of variance; the effects of non-normality and heterogeneity of variance on the t-test; and heterogeneity of variance and transformations of the scale. Of special value is a detailed consideration of a factorial design involving repeated measurements on several independent groups.

The major criticism to be made of the book regards its rather superficial treatment of statistical techniques. It appears to be designed to give the student clerical competence at the expense of a basic understanding of the mathematical and logical background of the various statistical methods. Again, there is occasional failure to point out the limitations of certain techniques through inability to meet the basic assumptions involved. For example, an entire chapter is devoted to the latin square design, but the author never does discuss the limited application of this design in psychological research due to inability to satisfy the assumption that the interactions are zero.

CHARLES W. ERIKSEN

LES MÉTHODES STATISTIQUES DANS L'EXPÉRIMENTATION BIOLOGIQUE.

By Ph. L'Héritier. Centre National de la Recherche Scientifique, Paris. 400 fr. (paper). 95 pp. + 5 charts; text ill. 1949.

Many statistical concepts and methods have become available to the experimenter in the last two hundred years. Selecting some and excluding others from an elementary exposition of the methods for biologists is a major task for any author. L'Héritier has managed to select and explain most of the principal ideas and methods in this compact book. It can be recommended as an introduction.

The first chapter points out the existence of two kinds of statistical problems (estimating unknown population parameters and testing hypotheses about parameters), the occurrence of discrete and continuous variables in nature, and the existence of two kinds of variability in data (errors of measurement, and natural variability). In the second chapter, the author gives a good introduction to the binomial, Poisson, and Gaussian distributions. He exhibits the derivations by use of elementary methods and explains their utility as models for biological variables. The general excellence of the discussion of the binomial distribution is marred only by the author's use of the product and addition rules of probability without stating them as rules.

The remaining chapters deal with percentages, contingency tables, the χ^2 test of goodness-of-fit, regression, correlation, analysis of variance, and design of experiments. In each case, the concepts are stated and illustrated simply and clearly. The author keeps before the reader the necessary distinction between population and sample, parameter and statistic.

The greatest inadequacies of the book appear to be (1) no mention of two kinds of errors in testing statistical hypotheses, (2) no index, (3) no mention of any other literature on statistical methods, and (4) no exercises or problems to test one's grasp of the ideas and methods.

EARL L. GREEN

PRACTICAL STATISTICS IN HEALTH AND MEDICAL WORK. *First Edition.*

By Ruth Rice Puffer; foreword by Hugo Muench. McGraw-Hill Book Co., New York, Toronto, and London. $3.75. xiv + 238 pp. 1950.

This book is a development of lectures given at the School of Public Health of the University of Chile. It covers a reasonably wide range of practical statistical problems, illustrated largely from the author's own experience in Tennessee. The book can be recommended for reading by anyone who is interested in learning what can be done with simple statistical methods in the study of public health problems. The discussion is throughout in practical rather than theo-

retical terms. It is not, and presumably was not intended as, a textbook.

There are a few points where opinions might differ on the procedures recommended. Whether the standard error of a death rate can properly be computed from the formula $\sqrt{pq/n}$, for example, seems very questionable. To the reviewer, the discussion of population estimation for post-census dates, and particularly the illustration chosen, seem likely to mislead. The implication seems to be that projection by arithmetic increase is a satisfactory method of handling a county population of the order of 25,000.

C. P. WINSOR

DE OMNIBUS REBUS ET QUIBUSDAM ALIIS

AMUSING QUOTATIONS FOR DOCTORS AND PATIENTS. *Edited by Noah D. Fabricant. Grune & Stratton, New York.* $3.00. x + 149 pp. 1950.

They really are amusing!

BENTLEY GLASS

A DICTIONARY OF SCIENTIFIC TERMS. *Pronunciation, Derivation, and Definition of Terms in Biology, Botany, Zoology, Anatomy, Cytology, Embryology, Physiology. Fourth Edition, revised and enlarged.*

By I. F. Henderson and W. D. Henderson; 4th ed. by John H. Kenneth. D. Van Nostrand Co., New York. $12.00. xvi + 480 pp. 1949.

The addition of approximately 2000 scientific words, many of which have been coined during the past ten years, makes the fourth edition of this dictionary as complete as any in the biological field. A spot check of some 150 words revealed no serious errors, although a specialist might insist upon a more narrowly restricted and rigid definition of some terms. The area covered includes botany and zoology in general, and anatomy, cytology, physiology, and embryology in particular.

A GERMAN-ENGLISH DICTIONARY FOR CHEMISTS. *Third Edition.*

By Austin M. Patterson. John Wiley & Sons, New York; Chapman & Hall, London. $5.00. xviii + 541 pp. 1950.

Patterson's *German-English Dictionary for Chemists*, which first appeared in 1917, has been a standard work of its kind and of great value not only to chemists, but to all scientists in their reading of technical German. Patterson's dictionary introduced the inclusion of non-technical German terms in a technical dictionary and thus avoided the need for two dictionaries for the reader whose knowledge of that language was not extensive. The Third Edition is increased over the Second, not only in the number of items, but also in the extensive number of definitions of words.

Certain minor criticisms are that the binding is not flexible, nor does it appear substantial enough for great usage; that there is no thumb index; and last, that the persistence of calling it a *German-English Dictionary for Chemists* seems unfair to the author and the publisher alike, for it is a dictionary of great value and use to all scientists, and not to chemists only.

M. C. SHELESNYAK

HILFSBUCH FÜR DIE BOTANISCHE MIKROSKOPIE. *By Reinhold Schaede. Georg Thieme, Stuttgart.* Kart DM 2.80 (paper). 48 pp. 1949.

This is essentially a handbook of microscopical techniques. Greatest emphasis is given to the staining of cell walls of various sorts, together with techniques for distinguishing their chemical composition, and to the techniques for demonstrating organic substances within the cell.

MICROSCOPE ELECTRONIQUE ET RECHERCHE BIOLOGIQUE. *Médecine et Biologie (Monographies publiées sous la direction de Marcel Florkin—No. 9).*

By Charles Grégoire; preface by Albert Claude. Editions Desoer, Liège; Masson & Cie., Paris. 135.- frs. belges (paper). 172 pp.; ill. 1950.

This is a very brief handbook intended to illustrate the application of the electron microscope to biological research. It is divided into two parts, the first describing the mechanism by which the electron microscope gains its great power of magnification, and the second illustrating some of the results obtained with biological material. For a short discussion intended for one who wants an insight into the workings and use of this instrument (and who can read French), the pamphlet is of great value. The diagrams are simple and the discussion clear. By contrast, the halftone illustrations are often very obscure. Simple directions are given for the preparation of material to be examined in the fields of molecular morphology, animal and plant viruses, bacteriophages, internal structure of cells and tissues (mitochrondria, chromosomes, collagen), muscle, coagulation of blood, etc. The pamphlet includes a well organized and selected bibliography, arranged according to the subject matter.

WILLIAM HOVANITZ

MACHINE SHOP METHODS.

By Lorus J. Milne. Prentice-Hall, New York. $3.00. viii + 376 pp.; ill. 1950.

Laboratory scientists who design and build their own apparatus—and this includes a large proportion of

research workers—should find Milne's book of great interest to them. It is a basic shop book which assumes no previous knowledge of shop techniques. In it, the author covers just about all the tools, machines, and methods the amateur needs to know. The style of writing is easy and understandable, and the text is profusely illustrated with good, clear drawings.

A. CHAPANIS

ANNUAL REPORT OF THE BOARD OF REGENTS OF THE SMITHSONIAN INSTITUTION. *Showing the Operations, Expenditures, and Condition of the Institution for the Year Ended June 30, 1948. Publication 3954.*

Smithsonian Institution, Washington, D. C. $2.50. x + 466 pp. + 100 plates + 1 chart + 1 map; tex. ill. 1949.

This volume contains the customary excellent selection of general scientific articles reprinted from other journals and in a few cases original. Those of a biological nature are as follows: Roentgen Rays against Cancer (John G. Trump); Algal Pillars Miscalled Geyser Cones (Roland W. Brown)—original; Concepts in the Conservation of Land, Water, and Wildlife (Ira N. Gabrielson); The Evolution and Function of Genes (A. H. Sturtevant); The Sense Organs of Birds (R. J. Pumphrey); Insect Control Investigations of the Orlando, Fla., Laboratory during World War II (E. F. Knipling)—original; The Golden Nematode Invades New York (W. L. Popham)—original; The Cork Oak in the United States (Victor A. Ryan & Giles B. Cook)—original; Remember the Chestnut! (Amanda Ulm); The Numbers and Distribution of Mankind (C. B. Fawcett); and Surviving Indian Groups of the Eastern United States (Wm. Harlen Gilbert, Jr.)—original.

The report from the National Zoological Park records the accession of 28 tarsiers and 9 tree shrews from the Philippines, among other rare animals. Those who live within visiting distance may indeed be glad of the chance to observe these interesting representatives of the lower primate families.

CARNEGIE INSTITUTION OF WASHINGTON. *Year Book No. 48–July 1, 1948 to June 30, 1949, with administrative reports through December 9, 1949.*

Carnegie Institution of Washington, Washington, D. C. $1.00 (paper); $1.50 (cloth). xxxvi + 258 pp. + 5 plates. 1949.

The *Yearbook No. 48* maintains its high value for biologists working in plant biology, embryology, or genetics and who wish to learn in advance of more detailed publication what their able group of colleagues in the Departments of the Carnegie Institution have lately accomplished.

At Stanford, California, biochemical investigations have concerned chloroplast pigments, the photochemical activity of disintegrated chloroplasts, the oxidation-reduction properties of chloroplasts, development of the mechanism for the evolution of oxygen, the nature of the transformation of protochlorophyll to chlorophyll, the action spectrum for the formation of chlorophyll, the uronides of leaves, and the development of spectroscopic equipment for further studies. The group working in experimental taxonomy has extended its studies of the ecological and geographical races and the formation of hybrids in *Potentilla*, *Achillea*, *Mimulus*, *Poa*, *Armeria*, and the Geraniaceae. In paleobotany, the investigation of the relic Chinese redwood *Metasequoia* has gone forward rapidly.

At Baltimore, Maryland, the current investigations have included studies of 8- and 9-day-old human embryos; the embryology of the skeleton and the histogenesis of cartilage and bone; the early development of the human vertebral column, and of defects of kidneys and ureters; atresia of the ovarian follicles, and the anatomy and physiology of the ovarian arteries; the cervical mucosa of the rhesus monkey; the blood vessels of the pregnant uterus and the physiology of the uterus; the physiology of menstruation; enzymes in embryonic tissues; the permeability of the human placenta and of capillaries; the amniotic fluid; the sex ratio of abortions; and the palatine ridges of primates, the number of young at birth, and number of nipples.

At Cold Spring Harbor, Long Island, McClintock has further analyzed the mutable loci *Ds* and *Ac* in maize, and has revealed an astounding range and variety of secondary position effects produced by the chromosome breakage and rearrangement which these 2 genes bring about. Workers on the genetics of bacteria have investigated the genetics of streptomycin resistance in *E. coli*, and of bacterial resistance to aureomycin, chloromycetin, and neomycin; the phenotypic expression of delayed mutants; the cytology of bacteria; the intracellular growth and genetics of bacteriophage. Other groups have made cytochemical studies with digestive enzymes on the organization of chromosomes; radiation studies of chromosomes; studies of mouse leukemia and the relation to it of a milk factor; investigations of genic action in mice, particularly of the maternal effect of the gene Fused which produces tail malformations; studies of gene action in the axolotl; transplantations of embryonic tails in mice and of grafts in the axolotl; serological studies of the difference between the normal and the Brachyury (T) mouse; and extensive investigations of the genetic structure of nature populations of tropical species of *Drosophila*, especially *D. willistoni* and *prosaltans*, conducted in Brazil.

For an annual report, this is most impressive.

BENTLEY GLASS

THE COLLOID CHEMISTRY OF THE SILICATE MINERALS. *Agronomy. A Series of Monographs Prepared Under the Auspices of the American Society of Agronomy. Volume I.*

By C. Edmund Marshall. Academic Press, New York. $5.80. x + 195 pp.; ill. 1949.

This excellent volume is the first of a series of monographs projected by the American Society of Agronomy and published under their auspices. The author has restricted the scope of this work in the main to evidence obtained from the study of reasonably pure materials, thereby relegating diverse applications to the background. The significant advances of the last twenty years are particularly emphasized. These have "transformed the study of the colloidal silicates from an almost hopeless empiricism to a well integrated part of mineralogy, colloid chemistry, soil science, ceramics and even of civil engineering. It would be difficult nowadays to find a better example of the way in which the elucidation of chemical structure has acted as a catalyst upon diverse applications."

There is a well written historical introduction, followed by a discussion of the various classes of silicates, which consist of silicon-oxygen tetrahedra arranged in chains, discrete rings, planar sheets, or three-dimensional frameworks, depending on the circumstances of bonding and the presence of other elements. There are separate chapters on the structural interpretation of chemical analyses, sizes and shapes of clay particles to which the electron microscope has contributed much information, and colloidal and optical properties. Adsorption by the clays, clay acids and their titration curves, ionic exchange reactions, and electrokinetic properties are discussed in four chapters, followed by consideration of the mechanical properties of clays, and of the properties of clay films. There are 85 text figures, including a number of atomic models and electron microscope photographs. There is a bibliography at the end of each chapter.

The reflective physiologist will find many interesting points in this story of the clays. For example, one can see, "as more becomes known about structure, how the emphasis changes and the impetus of the more fundamental investigations is directed toward behavior and its interpretation. . . . The colloidal nature of most clay minerals does not completely obliterate their separate and distinctive properties. . . . Again, viewing the matter in retrospect, one can see how frequently they (the colloid chemists) overemphasized the similarities of all extensive interfaces and failed to recognize the connection between surface atomic structure and colloidal properties. This situation has finally corrected rected itself, but not before many . . . had tried to explain all the peculiarities of clays in terms of their extensive surface."

EVELYN HOWARD

APPLICATION OF GEOLOGY TO ENGINEERING PRACTICE. *Berkey Volume.*

Chairman: Sidney Paige; papers by 18 contributors. Geological Society of America, New York. $2.75. xx + 327 pp. + 27 plates; text ill. 1950.

AN INDEX OF MINERAL SPECIES AND VARIETIES. *Arranged Chemically; with an Alphabetical Index of Accepted Mineral Names and Synonyms.*

By Max H. Hey. British Museum (Natural History), London. £1 10s. xx + 609 pp. 1950.

ELEMENTARY PILE THEORY.

By Harry Soodak and Edward C. Campbell. John Wiley & Sons, New York. $2.50. x + 73 pp. 1950.

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